A Preliminary Report on the Chemical Composition of Glaciers in the Eastern Tian Shan Mountains

Okitsugu Watanabe*, Nobuko Kanamori, Yutaka Ageta** and Wu Xiaoling***

(* Water Research Institute, Nagoya University, Nagoya, Japan; ** Faculty of Education, Yamaguchi University, Yamaguchi, Japan; *** Lanzhou Institute of Glaciology and Cryopedology, Academia Sinica, Lanzhou, China)

Abstract

The stundy on chemical composition of glaciers is important to know the characteristics of the material circulation in the atmosphere, hydrosphere, lithosphere and the interaction between these sphere.

Ninety samples of precipitation, snow, ice and melt water for chemical analysis were collected during the summer in 1981. These samples were brought to the laboratory in Nagoya University for the determination of F^-, Cl^-, SO_4^{2-}, NO_3^- and K^+, Na^+, Ca^{2+}, Mg^{2+}. Samples are classified into 5 groups, namely·New snow, snow cover, glacier ice, dirt band and surface melt water, The mean concentration and standard deviation of various chemical compotients in each group of samples are estimated. General tendency of the concentration among these groups are described. The concentration of each anion and cation in dirt band has 2-7 times higher value than it in other groups.

Ⅰ. Introduction

The Tian Shan Mountains are the most inland glacierized area in the world. The study on chemical composition of glaciers in such an area is considered to be important to know the characteristics of the circulation of the material in the atmosphere, hydrosphere and lithosphere, and the interaction between them. Therefore, a number of ice, snow and melt water samples for the chemical analysis were collected during the summer in 1981 by the China-Japan Cooperative Glaciological Expedition. A brief report with the data lists of the sampling and the chemical analysis is presented here.

Ⅱ. Method

Ninety samples of precipitation, snow, ice with debris and melted glacier ice waters were taken in the Mt. Bogda region and headwaters of the Urumqi River which is located about 140km west to southwest from the former, and they were brought to the laboratory in Nagoya University for chemical analyses. The frozen snow and glacier ice samples were melted at the sampling stations and were put in 100ml polyethylene bottles.

The containers used for storage of samples were cleaned with nitric acid and rinsed with deionised water. The chemical composition also has been measured in the laboratory.

These samples were filtered with millipore filter before the analyses. Dionex Model 10 Ion Chromatograph was used for the determination of F^-, Cl^-, SO_4^{2-}, NO_3^-, PO_4^{3-}, and Br^- in the samples.

The condition of the chromatograph was as follows: eluent, 0.003 M $NaHCO_3$ and 0.0024M Na_2CO_3; flow rate, 138ml/hr; separator column, 3 × 500mm anion first separator;

suppressor column, 6×250mm anion suppressor; injection volumn, 100ul.

Ⅲ. Results

Samples can be classified into 5 groups, namely, new snow, snow cover, glacier ice, ice of dirt band in glacier ice and surface melt water. Mean concentration and standard deviations of various chemical components in each group of samples are shown in Table 1.

Table 1. Mean concentrations (x) and standard deviations (σ_n) of various chemical components in each group of samples (unit: mg/l)

	New snow		Snow cover		Glacier ice		Dirt band		Surface melt water	
	x	σ_n	x	σ_n	x	σ_n	x	σ_n	x	σ_n
F^-	0.004	0.003	0.006	0.003	0.009	0.007	0.025	0.026	0.008	0.002
Cl^-	0.017	0.051	0.211	0.190	0.450	0.415	0.589	0.601	0.559	0.268
NO_3^-	0.250	0.175	0.202	0.147	0.263	0.278	0.247	0.178	0.315	0.200
SO_4^{2-}	0.263	0.106	0.203	0.162	0.457	0.862	3.391	6.358	1.042	0.512
Na^+	0.104	0.076	0.105	0.099	0.351	0.370	0.543	0.453	0.579	0.231
K^+	0.024	0.007	0.077	0.063	0.176	0.149	1.187	1.464	0.165	0.071
Ca^{2+}	0.112	0.039	0.351	0.356	2.018	2.525	11.525	9.613	3.139	1.894
Mg^{2+}	0.025	0.022	0.118	0.182	0.353	1.05	0.735	0.680	0.367	0.156

Although numbers of samples are different among these groups, it can be seen as general tendency that the concentrations in the snow cover are higher than the new snow and lower than the glacier ice except nitrate and sulfate. Such difference of the concentrations among these groups can be attributed to the condensation by infiltrated melt water from the surface where the chemical concentrations are high due to dry fall-out etc.. Such difference of the concentration of K^+, Ca^{2+} and Mg^{2+} is especially much. The concentrations of chemical components of the surface melt water excluding SO_4^{2-} are similar to those of the glacier ice, since the latter become the former by melting.

The dirt band among the groups in Table 1 is debris band in the glacier ice containing silt, sand and gravel with thickness of several cm ~ several 10cm. The dirt band near the glacier terminus is considered to be one kind of shear plane which is made by the thrust up of the glacier bottom due to differential movement of the glacier.

And also, the dirt band is formed in the accumulation area by falling stones from the surrounding rock wall.

The concentration of chemical components of ice in the dirt band are much higher than that of the other groups. For example, the concentration of each anion and cation in the dirt band has 2~7 times higher value than that in the glacier ice, which do not contain debris. Although the reason of such high concentration is not clear, two possibilities can be supposed. One is the condensation due to the pressure melting-refreezing process when the ice of the glacier bottom take in the debris from the base rock, and another is the dissolution by melt water of chemical components from the debris.

Typical two profiles of chemical concentrations of the west branch of Glacier No. 1 at the headwaters of the Urumqi river with values of the mol equivalent per litre are shown in Fig. 1 and 2.

Fig. 1 shows the vertical profiles of those in the snow cover at Station H-3 (4,075m a.s.l.)

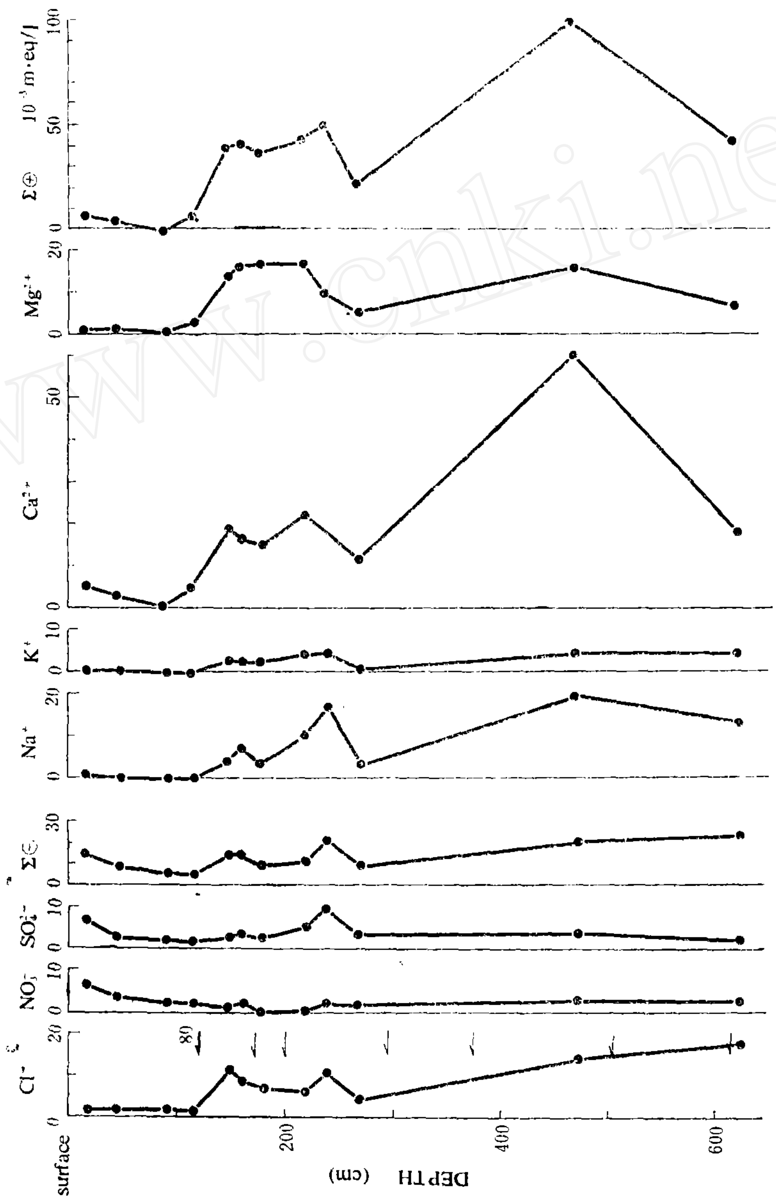

Fig. 1. Vertical profiles of concentrations of the chemical components in snow from the pit and boring cores at Station ***H.3****(4,075m a.s.l.) above the firn line on Glacier No.1 at the headwaters of the Urumqi river.*

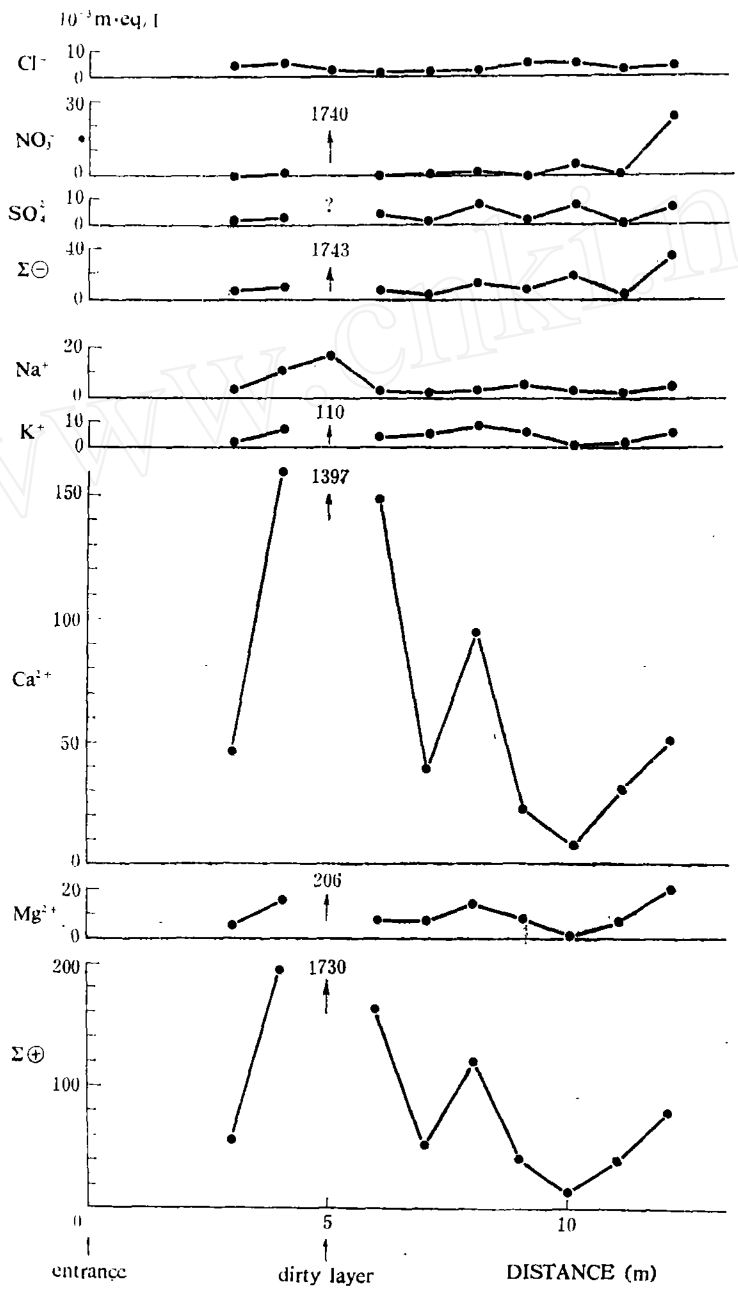

Fig. 2. Variation of concentrations of the chemical components in ice with the chemical components in ice with the horizontal distance in the ice tunnel at the bottom of Glacier No. 1.

above the firn line. Since this snow cover will change to the glacier ice through superimposed ice process, the profiles in Fig. 1 can be considered as that at the initial condition of the chemical components of the glacier ice.

It can be seen in Fig. 1 that the chemical components increase with depth due to the infiltration of melt water from the surface as mentioned above (Table 1). Snow of 6m thick in Fig. 1 consisted of deposited snow for 7 years, and granular snow which had not yet changed to the superimposed ice is remaining. Therefore, the melt water may reach deeper part and chemical concentrations may increase more with deeper layer. Since the measurement of HCO_3^- lacks, total cations are much higher than that of anions as seen in Fig. 1.

The snow cover will change to the glacier ice and reach the terminus by glacier flow. To see such continuity from the results in Fig. 1, chemical concentrations of the chemical composition of glacier ice in the ice tunnel at the bottom of the terminus of the same glacier are shown in Fig. 2. In this figure, variation of those with the horizontal distance from the entrance can be seen. It is notable in Fig. 2 that the concentrations of chemical components are very high at dirt layer, 5m from the entrance. The order of average concentrations of chemical components in the whole glacier is considered to be in a small range between the results at the lower part in the profiles of Fig. 1 and those of Fig. 2 excluding the results around the dirt layer.

The concentrations of 4 anions and 4 cations (mg/litre) of all samples are shown in Table 2 at the end of this report with the informations of sampling conditions.

The concentration of chemical composition in those samples and the comparison between the concentrations of these elements are very important for understanding of the mechanisms of the circulation and transportation of these elements. Further studies will be made continuously.

Table 2. Concentrations of chemical components of samples from the glaciers

1. The headwaters of the Urumqi River

1—1. Glacier No. 1

(unit: mg/l)

altitude (m)	position		material	date	F^-	Cl^-	NO_3^-	SO_4^{2-}	Na^+	K^+	Ca^{2+}	Mg^{2+}
4075	West branch St. H 3	105cm above summer surface in 1979	snow	July 13	0.006	0.049	0.37	0.31	0.021	0.009	0.10	0.009
		75	"	"	0.004	0.053	0.22	0.12	—	—	0.057	0.008
		30	"	"	0.012	0.058	0.15	0.067	—	—	—	—
		5	"	"	0.006	0.056	0.12	0.081	—	—	0.083	0.029
		30cm below summer surface in 1979	"	"	0.007	0.38	0.068	0.13	0.10	0.098	0.38	0.17
		40	"	"	0.008	0.32	0.12	0.17	0.15	0.10	0.34	0.20
		60	"	"	0.008	0.25	—	0.13	0.071	0.098	0.31	0.21
		100	"	"	0.010	0.22	—	0.26	0.23	0.17	0.45	0.21
		120	"	"	0.008	0.36	0.097	0.45	0.39	0.18	0.37	0.12
		150	icy	"	0.009	0.16	0.078	0.16	0.073	0.04	0.24	0.067
		354	ice	July 17	0.016	0.50	0.17	0.18	0.44	0.17	1.2	0.20
		504	"	"	0.016	0.63	0.16	0.10	0.29	0.16	0.36	0.083
4480	Tianger II (near the summit)	from the surface 0—9 (cm)	snow cover	August 16	0.007	0.22	0.083	0.11	0.14	0.074	0.67	0.027
		9—25	"	"	0.004	0.87	0.15	0.13	0.021	0.029	0.14	0.096
		25—33	"	"	0.006	0.26	0.18	0.17	0.22	0.21	1.6	0.81
		43	ice	"	0.012	0.39	0.15	0.19	0.23	0.33	1.1	0.67
		65	"	"	0.013	1.1	0.58	2.6	1.0	0.21	5.0	0.37
		83	"	"	0.006	0.21	0.10	0.10	0.051	0.022	0.28	0.072
4400	Tianger II (below the summit)		snow cover	August 16	0.005	0.15	0.39	0.31	0.092	0.040	0.16	0.026
			super-imposed ice	"	0.052	0.92	0.31	0.86	1.2	0.89	14	7.6
4130	East branch		snow	August 16	0.003	0.078	0.28	0.18	0.042	0.043	0.30	0.059
			super-imposed ice	"	0.013	0.46	0.45	0.21	0.39	0.26	0.77	0.43
			surface water	"	0.009	0.42	0.24	0.41	0.35	0.18	1.2	0.29
4000	East branch		snow	August 16	0.006	0.30	0.33	0.25	0.048	0.031	0.20	0.032
			glacier ice	"	0.014	0.66	0.54	0.56	0.48	0.19	1.3	0.43

(unit: mg/l)

altitude (m)	position		material	date	F^-	Cl^-	NO_3^-	SO_4^{2-}	Na^+	K^+	Ca^{2+}	Mg^{2+}
3820	Ice tunnel	from the entrance 3	ice	August 16	0.016	0.16	—	0.12	0.090	0.077	0.92	0.069
		(m) 4	〃	〃	0.004	0.21	—	0.15	0.25	0.28	3.2	0.18
		5	dirt band	〃	0.092	0.097	108	—	0.40	4.4	28	2.5
		6	ice	〃	0.003	0.083	—	0.20	0.061	0.17	3.0	0.086
		7	〃	〃	0.002	0.079	0.034	0.036	0.029	0.21	0.80	0.090
		8	〃	〃	0.006	0.091	0.094	0.43	0.082	0.33	1.9	0.17
		9	〃	〃	0.010	0.17	—	0.12	0.11	0.26	0.47	0.095
		10	〃	〃	0.011	0.21	0.29	0.39	0.057	0.023	0.17	0.016
		11	〃	〃	0.008	0.096	—	0.036	0.019	0.045	0.65	0.085
		12	〃	〃	0.011	0.15	1.5	0.34	0.10	0.23	1.0	0.24
		water channel	water	July 17	0.008	0.86	0.64	1.1	0.86	0.26	4.2	0.44
	west branch		surface water	July 17	0.008	0.52	0.075	0.84	0.47	0.16	1.8	0.27

1—2. Glacier No. 3

(unit: mg/l)

altitude (m)	position		material	date	F^-	Cl^-	NO_3^-	SO_4^{2-}	Na^+	K^+	Ca^{2+}	Mg^{2+}
3650	Pit No. 1	from the surface 20	ice	July 14	0.008	1.7	0.58	1.1	1.1	0.25	1.6	0.49
~3700		(cm) 33	〃	〃	0.035	2.0	0.53	3.5	1.4	0.74	17	0.84
	No. 2	20	〃	〃	0.007	0.91	0.32	0.83	0.67	0.19	3.3	0.43
		39	〃	〃	0.052	1.0	0.24	3.3	1.2	1.7	20	1.3
	No. 3	20	〃	〃	0.015	1.1	0.51	1.9	1.2	0.42	4.1	0.47
		40	〃	〃	0.018	1.0	0.20	1.6	0.70	0.32	17	0.49
	No. 4	20	〃	〃	0.013	0.18	0.074	0.48	0.14	0.24	0.78	0.23
		45	〃	〃	0.007	0.21	0.067	21	0.23	3.5	21	0.33
		65	〃	〃	0.015	1.1	0.46	5.5	0.96	0.50	6.2	0.47
	St. D		glacier ice	August 15	0.009	1.5	0.59	0.36	1.1	0.21	5.1	0.42
	St. D B	surface	〃	〃	0.005	1.1	0.70	0.77	1.4	0.25	3.8	0.46
	St. B	〃	〃	〃	0.007	0.88	0.33	0.48	0.76	0.19	3.3	0.57
	St. E		〃	〃	0.008	0.75	0.31	0.68	0.57	0.16	2.8	0.30
	near St. B		flowing water	July 14	0.009	0.89	0.26	1.1	0.69	0.088	2.6	0.35
	St. D		melt water	August 15	0.009	0.72	0.46	1.9	0.70	0.27	4.7	0.48
	terminus		flowing water	〃	0.009	0.83	0.53	1.4	0.70	0.15	5.0	0.58

2. Mt. Bogda region

2—1. The base camp (unit: mg/l)

altitude (m)	position		material	date	F^-	Cl^-	NO_3^-	SO_4^{2-}	Na^+	K^+	Ca^{2+}	Mg^{2+}
3640			snowfall	July 30 night	0.003	0.25	0.091	0.12	0.21	0.026	—	0.062
			〃	31, 12h 〃	0.003	0.18	0.070	0.26	0.038	0.014	—	0.014
			〃	August 4, 5	0.006	0.15	0.18	0.42	0.063	0.031	0.15	0.017
			〃	〃	0.005	0.10	0.36	0.25	—	—	0.073	0.007

2—2. Glacier D 1 (unit: mg/l)

altitude (m)	position		material	date	F^-	Cl^-	NO_3^-	SO_4^{2-}	Na^+	K^+	Ca^{2+}	Mg^{2+}
3700	St. No. 3		snowcover	August 1	0.002	0.092	0.088	0.031	0.029	0.021	—	0.008
4006	St. No. 9		〃	〃	0.001	0.070	0.085	0.049	0.025	—	—	0.016
		depth 185—190cm	ice	〃	0.010	0.49	0.16	0.26	0.19	0.20	0.73	0.26
3838	St. No. 6			5	0.003	0.11	0.17	0.17	0.01	—	0.035	0.007
3976	St. No. 8		〃	〃	0.005	0.89	0.056	0.057	—	—	—	0.003
3770	middle part		debris laden layer	6	0.065	0.21	0.045	0.061	0.13	0.043	0.40	0.063
			〃	〃	0.099	0.14	0.057	0.11	0.18	0.29	5.7	0.78
			〃	〃	0.013	0.11	0.46	0.13	0.22	0.41	1.3	0.48
			〃	〃	0.008	0.14	—	0.099	0.082	0.22	1.3	0.17
3620	St. No. 1 No. 2		ice	6	0.005	0.11	0.055	0.033	0.021	—	0.065	0.029
3600	terminus		pond water	1	0.005	1.6	2.1	3.9	1.9	0.57	11	1.2
			surface water	〃	0.011	0.22	0.28	1.5	0.59	0.22	6.1	0.57

2—3. Glacier D 5

(unit: mg/1)

altitude (m)	position		materials	date	F^-	Cl^-	NO_3^-	SO_4^{2-}	Na^+	K^+	Ca^{2+}	Mg^{2+}
3677	St. No. 3		stagnant ice	August 3	0.007	0.14	—	0.038	0.079	0.048	0.10	0.045
3702	St. No. 4		ice	″	0.008	0.084	0.038	0.033	0.080	0.21	5.6	0.59
			″	″	0.003	0.20	0.051	0.047	0.034	0.026	0.17	0.038
3725	St. No. 9		″	″	0.005	0.22	0.023	0.047	0.067	0.17	0.23	0.072
			″	″	0.011	0.19	0.051	0.30	0.24	0.16	7.0	0.13
			″	″	0.005	0.23	0.080	0.061	0.13	0.086	0.37	0.072
3722	St. C		″	″	0.007	0.20	0.034	0.064	0.077	0.091	0.19	0.11
			flowing water	″	0.005	0.11	—	0.13	0.073	0.050	0.45	0.079
3749	St. D		ice	″	0.004	0.53	0.43	0.53	0.51	0.22	1.8	0.24
			dirt layer	″	0.008	0.98	0.38	0.72	0.89	0.25	3.5	0.40
3660	St. T1		ice	″	0.003	0.20	0.075	0.022	0.15	0.057	0.039	0.019
3663	St. T4		″	″	0.002	0.17	0.045	0.023	0.092	0.053	0.030	0.010
3670	St. T7		″	″	0.004	0.11	0.030	0.028	0.023	0.055	3.5	0.15
3652	St. A		″	″	0.004	0.21	0.066	0.047	0.12	0.086	0.58	0.12
	below terminus		″	″	0.005	0.23	0.056	0.059	0.15	0.11	0.65	0.074
3720	strain grid		″	″	0.004	0.39	0.13	0.12	0.29	0.095	1.2	0.18
3890	St. F		″	″	0.004	0.29	0.14	0.26	0.33	0.060	0.73	0.13
			flowing water	″	0.006	0.46	0.033	1.0	0.78	0.11	1.9	0.24
3730	near strain grid		ice	August 7	0.008	0.20	0.80	0.80	0.11	0.067	0.38	0.043
3890	St. F	surface	snow	″	0.008	0.11	0.62	0.74	0.021	0.012	0.22	0.024
			glacier ice	″	0.013	0.31	0.24	0.086	0.32	0.18	0.38	0.18
			bubbly ice	″	0.009	0.33	0.17	0.32	0.25	0.055	0.57	0.16
			clean ice	″	0.010	0.21	0.17	0.57	0.36	0.050	0.58	0.12
3765	St. No. 6		median moraine	″	0.011	0.19	0.25	0.19	0.12	0.036	0.54	0.076
3755	around St. No. 7		ice	″	0.006	0.45	—	0.019	0.45	0.078	3.1	0.12
3675	St. No. 2 3		dead ice	″	0.008	0.11	—	0.019	0.040	0.034	0.087	0.016

天山东部冰川化学成分的初步分析

渡边兴亚* 金森畅子* 上田 丰** 武筱舲***
（*日本名古屋大学水圈科学研究所； **日本山口大学教育学部； ***中国科学院兰州冰川冻土研究所）

摘 要

冰川化学成分的研究对了解物质在大气圈、水圈、岩石圈中的循环及其相互作用是十分重要的。

1981年夏天为化学分析曾采集了降水、冰雪以及融水的90个样品。这些样品带至名古屋大学进行了 F^-、Cl^-、SO_4^{2-}、NO_3^- 和 K^+、Na^+、Ca^{2+}、Mg^{2+} 的测定。划分出五组：新雪、雪盖、冰川冰、污化层以及表面融水。计算出各组每种离子的平均浓度和均方差。给出了各组浓度变化的总趋势。污化层中阴离和阳离子的浓度较其它组高 2 至 7 倍。