Glaciological and Chemical Characteristics of Snow in the Inland Plateau, East Queen Maud Land, Antarctica

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南極東クィーンモードランド内陸氷床における雪の雪氷学的ならびに化学的特性

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要旨：1985年に行った東クィーンモードランド氷床内陸部の調査により，その頂部 Valkyrjedomen の最高地点 (77°22′ S, 39°37′ E, 3807 m) やその氷床表面形態が明らかになったほか，雪の地球化学的特性がわかった．内陸に向かうにしたがい，雪の電気伝導度は大きくなり，pH は低くなる傾向が認められたが，特に標高 3600 m 以上の内陸部でこの傾向が顕著であった．これは南極氷床内陸部では，成層圏起源のエアロゾルやガスが，雪の化学的特性を規定しているためと考えられる．

Abstract: Glaciological observations on the high plateau in the East Queen Maud Land, Antarctica, were carried out along a route of the oversnow traverse, by the 25th and 26th Japanese Antarctic Research Expeditions in 1984 and 1985. The surface topography of the dome-like plateau (Valkyrjedomen, which is the second highest in Antarctica) and the positions of ice divides were determined clearly. The position and altitude of the highest place of the dome are 77°22′S, 39°37′E and 3807 m a.s.l.

Snow drift samples were collected along the route from Mizuho Station to Valkyrjedomen and were melted carefully in a snow vehicle. The value of electric conductivity of the melted snow samples at 0°C was obtained before storing in the pre-cleaned bottles. In a home laboratory, pH measurements of the samples were carried out. It was revealed that the high electric conductivity and low pH values were found among the snow samples collected in the dome area, especially around the region higher than 3600 m a.s.l. The region has the different glaciological characteristics from those in the katabatic wind region, that is, the lower degree of the surface inclinations, the lower net accumulation, the more smooth surface morphology, the lower ram hardness of surface snow layer and the higher lapse rate of snow temperature at 10 m depth. Taking the comparatively higher concentration of artificial radio nuclides reported in the other Antarctic inland area into consideration too, the glacio-chemical environments in the Antarctic inland region are thought to be characterized by the transportation of the stratospheric aerosols or gases.

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1. Introduction

Glaciological research project in the East Queen Maud Land, Antarctica, was carried out by the 23rd to the 27th Japanese Antarctic Research Expedition (JARE-23～-27) from 1982 to 1986.

In this paper, we show and discuss the glaciological results observed in the area, one of the highest inland plateaus in Antarctica, traversed by the JARE-25 and the JARE-26. In 1984, the team of the JARE-25 extended a route from Mizuho Station, established the Advance Camp at 74°12′S, 34°59′E and 3200 m a.s.l. and came back to Mizuho Station through the Yamato Mountains (FUJII *et al.*, 1985). The team of the JARE-26 in 1985 reached the highest place of the dome-like plateau called Valkyrjedomen, south of the Advance Camp, and went down to the Asuka Camp, located north of the Sør Rondane Mountains. During this glaciological traversing, the investigations on the snow depositional environments were carried out along the route.

2. Glaciological Observation

2.1. Geomorphological observations

The positions and altitudes of every overnight spot along the route were determined by the Navy Navigation Satellite System (NNSS). The ice thickness was measured every 2 km along the route by the radio echo sounding and the gravity measurement. The shape of the dome called Valkyrjedomen and the positions of ice divides were surveyed and became clearer than Levanon's ice elevation map based on data obtained by laser altimetring from balloons (LEVANON, 1982). The highest point was carefully determined by measuring the inclination of ice sheet skyline at several places along the traverse route. The position and altitude are 77°22′24″S, 39°36′50″E and 3807 m a.s.l. The altitude indicates that Valkyrjedomen is the second highest dome in Antarctica.

The ice thickness at the highest point was determined to be 2833 m (AGETA *et al.*, 1987a) but there remained a little uncertainty because of very weak radio echo from the bedrock. The more detailed description will be published later.

2.2. Depositional environment of the snow surface

The net accumulation was obtained at every 2 km along the route established in 1984 by remeasurement of the stakes in 1985. Annual accumulation observed was generally in the range between −5 and +40 cm of snow in the area above 3000 m a.s.l. (AGETA *et al.*, 1987a). The configuration of the surface snow cover in the area was recorded, dividing surface features into some types. At several points along the route, the snow temperature of 10 m depth from the surface was obtained. Areal difference of the vertical profile of the snow hardness was also observed along the route. All the results support that the characteristics of the katabatic wind region in the plateau disappeared around the area higher than 3400–3600 m as reported by AGETA *et al.* (1987b). The altitudinal limit of katabatic wind in the area is 400 m

higher than that reported in the south of Mizuho Station (WATANABE, 1978). However, the surface slope of both areas, where the katabatic wind is not dominant, is less than 2.0×10^{-3}, since the strength of the katabatic wind depends on the surface slope. Consequently, it can be said that the surface slope is the important factor among the geomorphological conditions for the surface wind system which controls the depositional environments of the snow surface.

3. The Chemical Characteristics of the Snow Drifts

The electric conductivity (EC) and pH of the melted snow drift samples collected along the routes were measured. The snow drift was taken into the pre-cleaned bottle of 1 *l*, keeping away from the route windward. The value of EC of each sample was obtained at 0°C after melted in a snow vehicle. The high EC value was obtained in the inland area, especially around the dome, as shown in Table 1 and in Fig. 1.

The residue was put into another pre-cleaned bottle of 100 m*l* and was taken back to a laboratory in Japan. The pH was measured in the laboratory, using the separated glass and calomel electrodes with a suction pump (FAR101F, TOA Electronics Ltd., Japan) which were ideal for measuring the ion-less water not contaminating the samples by potasium chloride solution.

There existed a clear relationship between the values of EC and pH as shown in Fig. 2 and also in Table 1. The same relationship was reported on snow samples from shallow pit wall at Dome C (DELMAS *et al.*, 1982), where the electric conductivity and the positively correlated acidity calculated from the pH value in the liquid phase of snow samples increased from 1 to 2.5 μS/cm and from 2 to 6 μEq/*l*, respectively. The value of pH shown in Fig. 2 was converted into the value of acidity in Fig. 3, where it is clearly observed that the both values around the dome area are higher than those at Dome C: *i.e.* the values of EC and acidity are in the range from 1.4 to 9.8 μS/cm and from 0.8 to 25 μEq/*l*, respectively.

On the contrary, the opposite relationship, that the value of pH increased with the increase in EC value, was observed in the snow samples obtained at Syowa Station located on an island in the Southern Ocean as shown in Fig. 4. The effects of the sea, presented in the snow depositions, on the values of EC and pH appeared on the fact that high pH values occurred together with high EC values.

Table 1. Values of electric conductivity and pH in the surface snow drift samples obtained along the traverse routes of the inland area of the East Queen Maud Land. The value of pH is shown in parentheses.

Route	Number of samples	Mean	Standard deviation	Maximum	Minimum
IM	32 (/)	2.15 (/)	0.56 (/)	3.2 (/)	1.4 (/)
ID	42 (38)	3.48 (5.16)	1.62 (0.29)	9.8 (6.05)	1.7 (4.60)
DF	13 (12)	4.45 (4.91)	0.82 (0.08)	5.4 (5.00)	3.2 (4.75)
IR	7 (7)	3.74 (5.15)	1.72 (0.20)	6.8 (5.46)	2.1 (4.78)
KR	5 (5)	2.64 (5.18)	0.90 (0.15)	3.8 (5.38)	1.8 (5.01)
IR	3 (3)	2.20 (5.30)	0.62 (0.24)	2.6 (5.58)	1.4 (5.13)

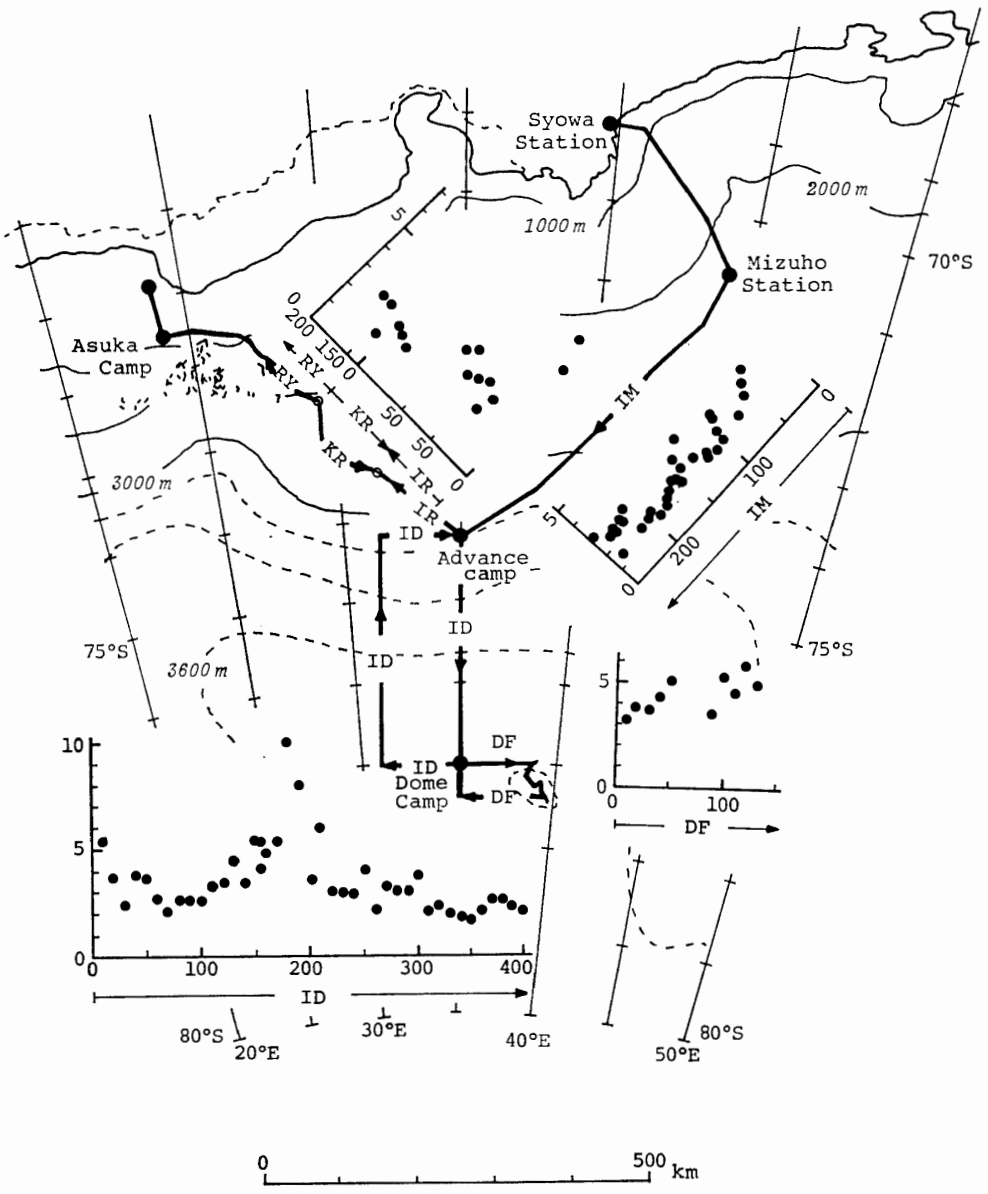

Fig. 1. Values of electric conductivity of the melted surface snow drift samples obtained along the traverse routes of the inland area of the East Queen Maud Land. The names, IM, DF, ID, IR, KR and RY, show the codes of each traverse route and the numbers are given every two kilometers distances toward the the arrows. All the values are expressed in the unit of μS/cm.

4. Discussion

It can be said that the high EC and the low pH values are glacio-chemical characteristics of snow in a high inland area of Antarctica.

In Fig. 5, the values of EC and pH in the inland area are plotted against the altitude of the sampling points. The values of high EC and low pH are sometimes observed in the region higher than 3600 m a.s.l. The region coincides with the region

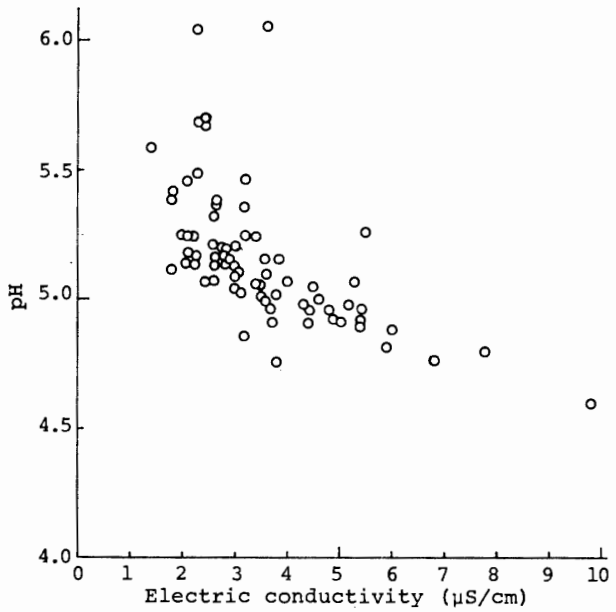

Fig. 2. Relationship between the values of electric conductivity and pH of the melted surface snow drift samples obtained along the traverse routes of the inland area of the East Queen Maud Land.

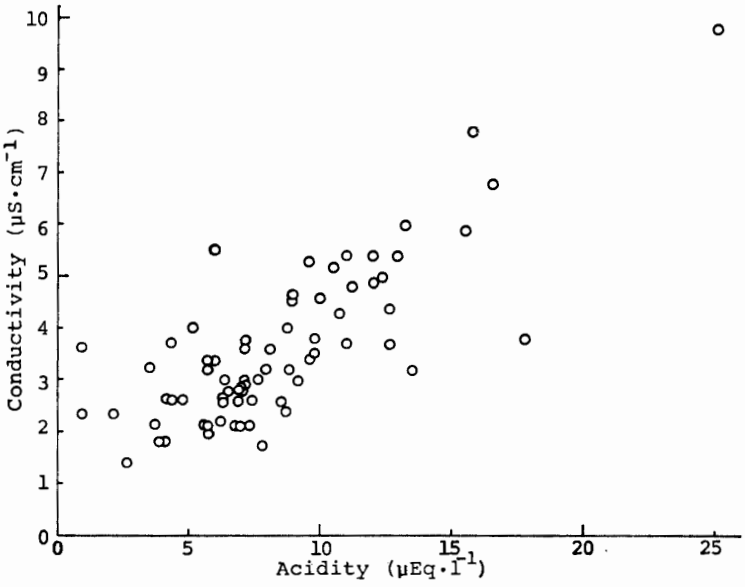

Fig. 3. Relationship between the values of acidity and electric conductivity of the melted surface snow drift samples obtained along the traverse routes of the inland area of the East Queen Maud Land. The value of acidity was calculated from the value of pH in the liquid phase.

where the glaciological characteristics in a katabatic wind region disappear as reported by AGETA *et al.* (1987b).

More acid substances would be contained in the snow drift around the dome region, which would be confirmed later more clearly by the determination of major

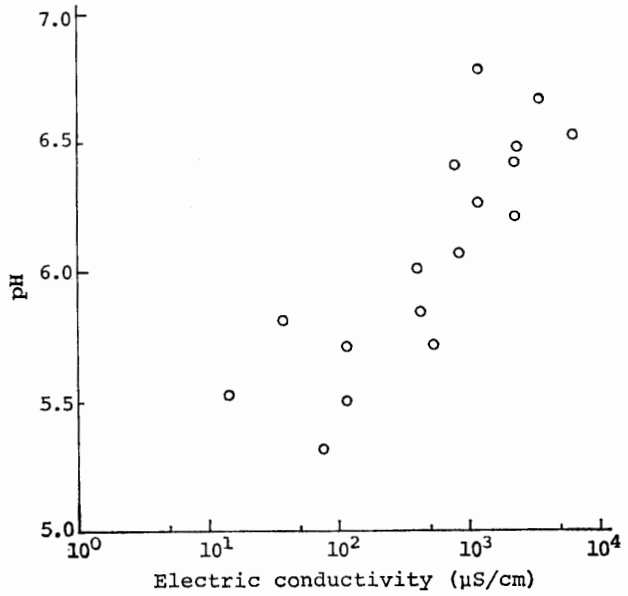

Fig. 4. Relationship between the values of electric conductivity and pH of the melted snow samples obtained at Syowa Station near sea side.

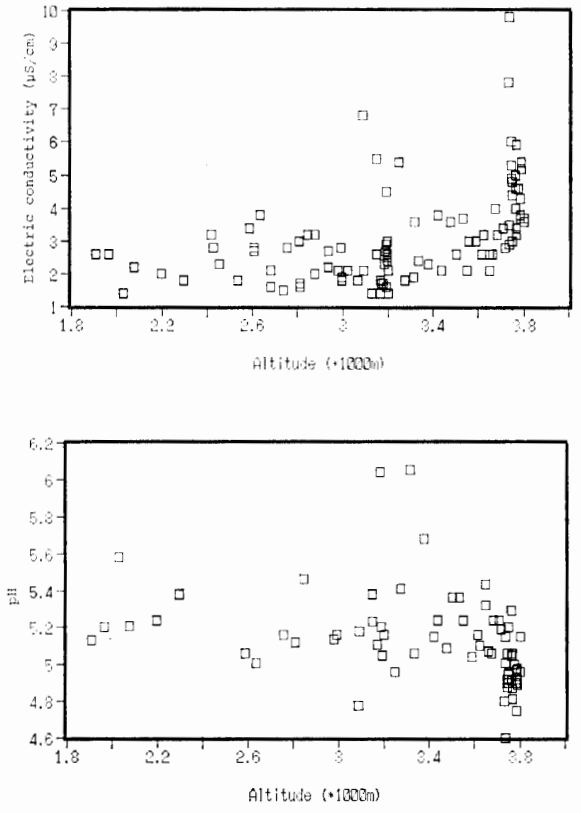

Fig. 5. Electric conductivity and pH in the surface snow drift samples obtained along the traverse routes in the inland area of the East Queen Maud Land versus the altitude of the sampling points.

*Table 2. Tritium content and gross beta activity observed in the 1965–1966 snow layer at several points, Antarctica. The value shown by * is the one in the 1966 precipitation and expressed by the range between the minimum and maximum values.*

Point	Tritium (TU)	Gross β (dpm/kg)	Reference
South Pole	2800 (1800)	40 (42)	JOUZEL *et al.* (1979)
Dome C	700	50	PETIT *et al.* (1982)
Adélie Coast	70	35	RAVOIRE *et al.* (1970)
Halley Bay	126*–624*	—	IAEA (1971)
Mizuho (H128)	—	3	WATANABE (1978)

ions.

The concentration of tritium became higher in the inland area, Antarctica, as reported by JOUZEL *et al.* (1979). In Table 2, the concentrations of artificial radio nuclides, tritium and gross beta activity of the 1965–1966 layer reported from some places in the Antarctica are listed. The table indicates that the concentration of artificial radio nuclides was higher in the Antarctic inland area than in the coastal area. It is, therefore, suggested that the chemical characteristic of the inland snow drift is reflected by the transportation of the stratospheric aerosols or gases much more than that of snow in the Antarctic coastal area.

The further analyses of the snow drift samples, as to artificial radio nuclides, major ions and so on, will be needed, and we only discuss here about the depositional environment in the Antarctic inland plateau, on the basis of the preliminary results of EC and pH. Further discussion will be presented later.

5. Conclusion

The snow drifts obtained around the dome-like plateau, Valkyrjedomen, which is the second highest in the Antarctica, are characterized by high values of electric conductivity and low values of pH in the liquid phase. The region with these chemical characteristics of snow coincides with the region where the katabatic wind is weak or negligible.

In the snow samples obtained at Syowa Station located on an island in the Southern Ocean, it was observed that the value of pH increased with the increase in the values of electric conductivity.

Taking the concentration of artificial radio nuclides, reported from various parts of Antarctica, into consideration, chemical characteristic of snow in the dome region can be said to be reflected by the transportation of the stratospheric aerosols or gases.

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