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# On the Characteristics of Aerosol Particles Collected at Rumoi, Hokkaido

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**Abstract**

Aerosol particles were collected at Rumoi, Hokkaido in the spring of 1995 and 1996 in order to analyze their size, shape and elemental compositions by the use of the SEM-EDX system. From the trajectory analysis of air mass which contained the aerosol particles, it was found that the particles were generated in the northern part of China and Mongolia. These particles were classified into three categories by their shape and elemental compositions: (1) The particles, which consisted of minerals such as gypsum, quartz and aluminosilicate; these particles had an irregular shape; (2) Sea salt particles having a square shape; (3) Mixed particles, which were combined with soil particles and sea salt particles: they made up 13.5% of the total number of aerosol particles.

## 1. Introduction

It is well known that aerosol particles act as condensation nuclei or ice nuclei in snow clouds which appear on the west coast of the northern part of Japan and bring on heavy snow. Isono et al. (1959) reported that particles activated as ice nuclei are soil particles generated in arid areas of the Asian continent.

On the other hand, elemental analysis of individual particles has been carried out recently by the use of electron micro-analyzer. Okada and Kai (1995) made an elemental analysis of soil particles which were sampled in an arid area of the northern part of China, and identified the minerals of the soil particles, which consisted of yellow sand. The results of their analysis give useful suggestions for classifying aerosol particles collected on the west coast of Japan.

It is also considered that soil particles are affected in shape and element by contact with water-soluble particles during the movement over the Japan Sea. Okada et al. (1987) found that most of the Asian dust-storm particles collected in Nagoya, Japan were surrounded by water-soluble material. Additionally, Sakurai (1989) reported that particles mixed with both soil particles and sea salt particles were found in aerosol collected on the west coast of Hokkaido, Japan.

These mixed particles play an important role in the formation of snow crystals in clouds. Namely, it is believed that they act first as condensation nuclei and then as ice nuclei. This paper will report on the examination, by the use of the SEM-EDX system, of the number and shape of the mixed particles collected at Rumoi, Hokkaido.

## 2. Sampling and analysis

Observations of the aerosol particles were made at Rumoi, Hokkaido on 7 June 1995 and 19 March, 23 April, and 29 May 1996. Table 1 shows the meteorological conditions when the observations were carried out at Rumoi. In the case of the observation made on 23 April, the wind direction on the ground was east-southeast.

Table 1. Meteorological conditions at Rumoi.

| Date | Weather | Wind direction | Wind speed (m/s) | Air Temp. (°C) |
|---|---|---|---|---|
| 1995-06-07 | clear | NW | 5.0 | 16.2 |
| 1996-03-19 | snow | W | 5.7 | −0.2 |
| 1996-04-23 | cloudy | ESE | 6.0 | 13.0 |
| 1996-05-29 | cloudy | WSW | 7.9 | 22.2 |

In the case of the observation of 19 March, replicas of snow crystals were made in order to compare the center nucleus of the snow crystal with aerosol particles.

The aerosol particles were collected on filter paper, having the pore size of 0.05 $\mu$m, by the use of an impactor. The filter paper was cut into a small pieces of about 5×5 mm square, and the pieces were mounted on the stage of an electron microscope. The stage was then evaporated by carbon. The elemental compositions and images of individual particles were analyzed by the electron microscope (SEM) with an energy dispersive X-ray analyzer (EDX) (detectable atomic number$\geqq$11 (Na)).

In order to identify the minerals of the particles, the peak intensity of the characteristic X-ray of the elements was compared with that of standard material. Moreover, weight ratio between the two elements contained in a particle was calculated from the ratio between the two peak intensities in terms of that of the standard material.

## 3. Results

### *3.1 Trajectory of the air mass*

In order to identify the locations which were generated the aerosol particles, the trajectory analysis of the air mass containing them was made by using the 700 hPa weather map. According to Iwasaka et al. (1983), the lidar measurements indicated that there were two dust clouds, one at a height of 6 km and the other at 2 km. Although there were no measurements of the vertical distribution of dust clouds in this observation, it is estimated by using figures as to the average height that the particles were transported with the air mass at a height of about 700 hPa.

The trajectories of the air masses are shown in Fig 1. It is seen from the figure that the locations of the air masses which arrived in Rumoi are scattered throughout the northern part of China and Mongolia. Therefore, it is considered that the soil particles were generated in arid areas of the continent. The sea salt particles in the aerosol would have been added during the traverse over the northern part of the Japan Sea.

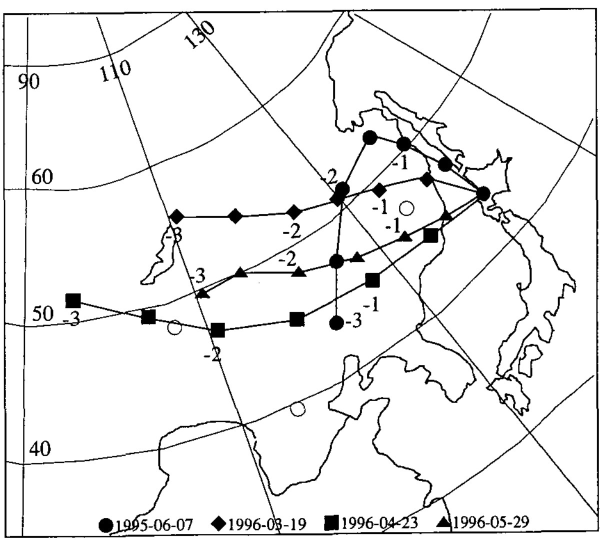


Fig. 1. Trajectiories of air masses

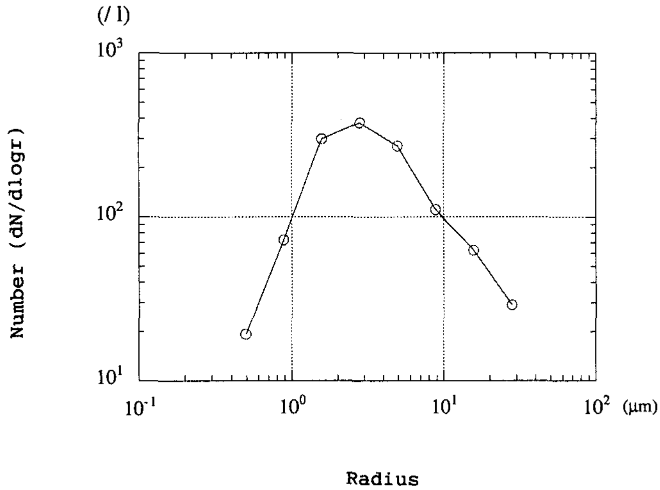


Fig. 2. Size distribution of aerosol particles

### 3.2 *Elemental analysis*

Size distributions of the particles were obtained by measuring the size of images displayed with the electron microscope. One of these is shown in Fig. 2. The maximum of number concentration is found in a radius of about 3 $\mu$m. This result supports the size distribution of Asian dust particles, or yellow sand "Kousa", observed by many investigators. The elemental composition of particles smaller than 0.5 $\mu$m in size could not be analyzed by the SEM-EDX system. Therefore, the size distribution of particles $\leqq 0.5$ $\mu$m was obtained in this observation.

Elements contained in individual particles were identified by EDX for particles larger than 0.5 $\mu$m in size. The percentage of the particles which contained the various elements, in relation to the total number of particles, is shown in Figs. 3 and 4 in the cases of the observations of 23 April and 29 May, respectively. It is seen from these figures that there is a difference concerning elements composed in the particles between both observations. Namely, the former consists of a large number of sea salt particles and a small number of soil particles. On the other hand, the latter consists of more soil particles than sea salt particles. As seen in Fig. 1, both air masses traveled through almost the same path on the Asian continent and over the Japan Sea. Therefore, the difference may be produced by the meteorological conditions and the roughness of the sea surface during the traverse.

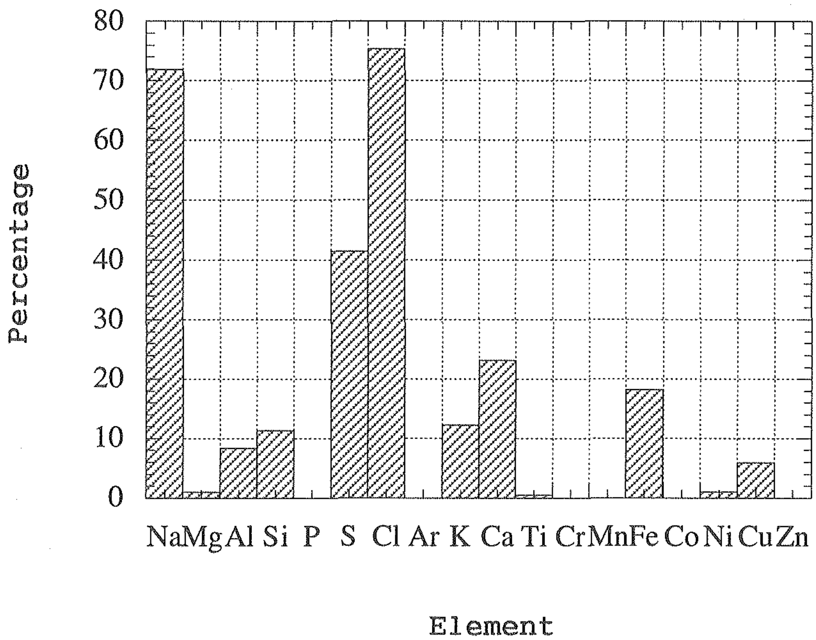


Fig. 3. Percentage of the particles containing various elements on 23 April 1996.

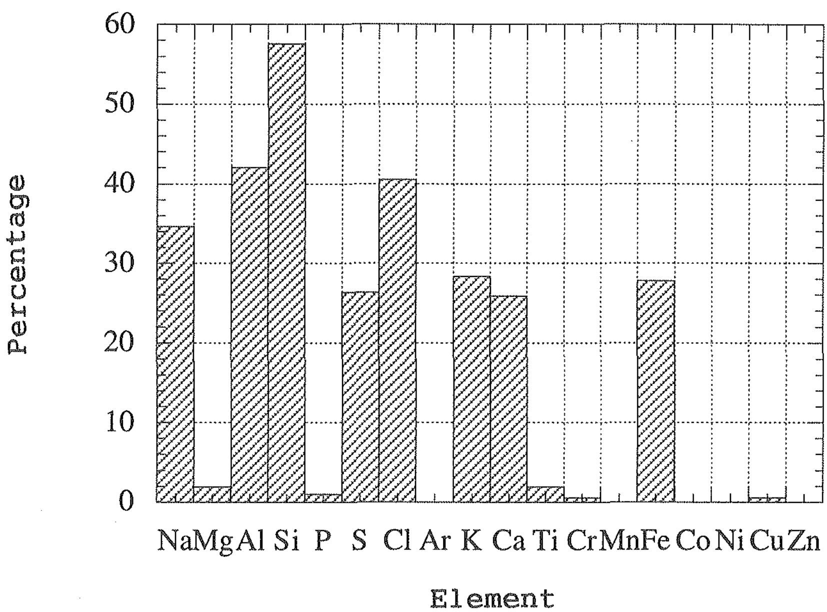


Fig. 4. Percentage of the particles containing various elements on 29 May 1996.

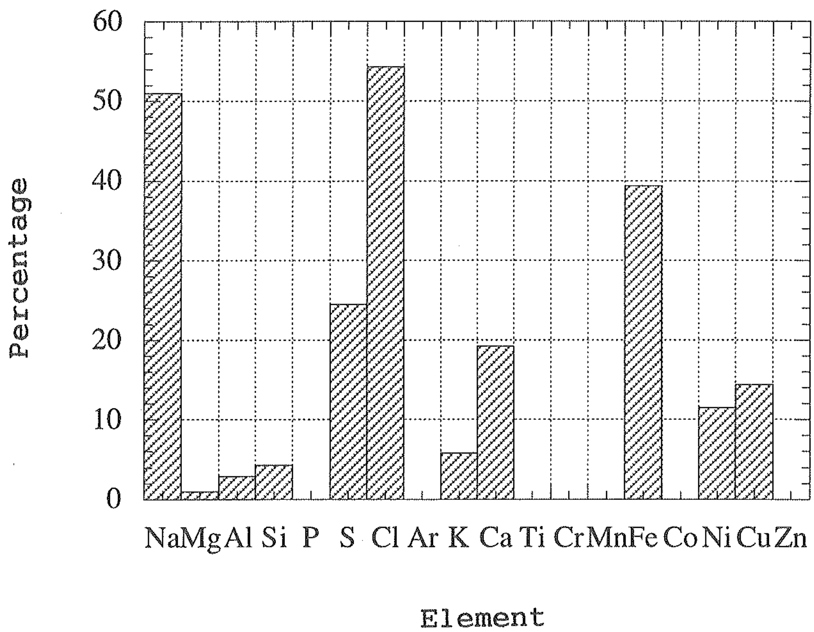


Fig. 5. Percentage of the airborne particles containing various elements on 19 March 1996.

The percentage for the elements composed in the aerosol particles and solid particles found in snow crystal for the observations of 19 March are shown in Figs. 5 and 6, respectively. The particles in air consist mainly of sea salt particles, but the solid particles in snow crystal appear to be exclusively soil particles. It is considered from the figures that soil particles contained in the airborne particles acted selectively as nuclei produced cloud droplets and ice crystals.

### *3.3 Features and elemental composition of particles*

1049 particles were analyzed by the SEM-EDX system. They were classified into sea salt particles and soil particle by their features and elemental composition. A typical sea salt particle is shown in Fig. 7 with Mark A. The flat surface of the NaCl crystal appears with a square shape in the figure. The length of the side-line of the crystal is about 5 $\mu$m. The Cl/Na of sea salt particles observed is 1.64. This value is nearly equal to that of the NaCl crystal. The number of particles detected as sea salt particles is 291.

Several kinds of soil particles generated on the Asian continent were found.

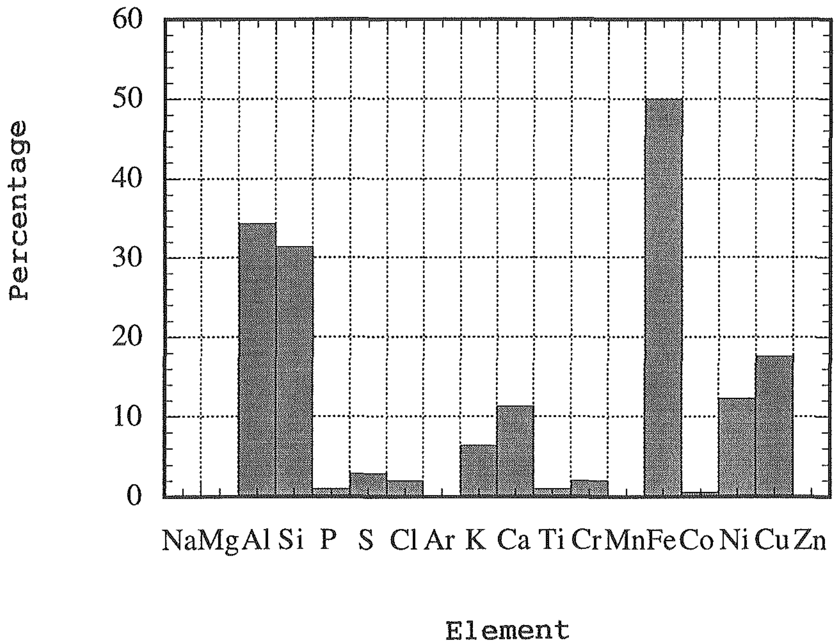


Fig. 6. Percentage of the particles in the central part of the snow crystals containing various elements on 19 March 1996.

One of these is gypsum ($CaSO_4 . 2H_2O$), shown in Fig. 7 with Mark G. The S/Ca weight ratio of particles which contain S and Ca is 1.0. This ratio is nearly equal to 0.8 of the weight ratio of gypsum. Next, quartz ($SiO_2$) was found. From EDX analysis of this particle, only a spectrum of Si appeared. The flat surface of the crystal is seen in the SEM image.

Moreover, many other soil particles were analyzed, as shown in Fig. 8. These particles contain characteristic elements which are composed of soil minerals such as Mg, Al, Si, K, Ca and Fe. The element which showed maximum weight ratio is Si. The second most abundant element is Al. Therefore, it is considered that these particles are aluminosilicate. The number of soil particles totaled 398.

Finally, mixed particles with both soil and sea salt particles were found with high frequency in a group of giant particles. Fig. 9 is a SEM image of a mixed particle. The particle is a soil particle combined with small sea salt particles,which can be seen in the central part of a soil particle. EDX spectra of the particle are shown as the combination of spectra of the NaCl with that of the minerals. In this case, the particle is a large soil particle combined with

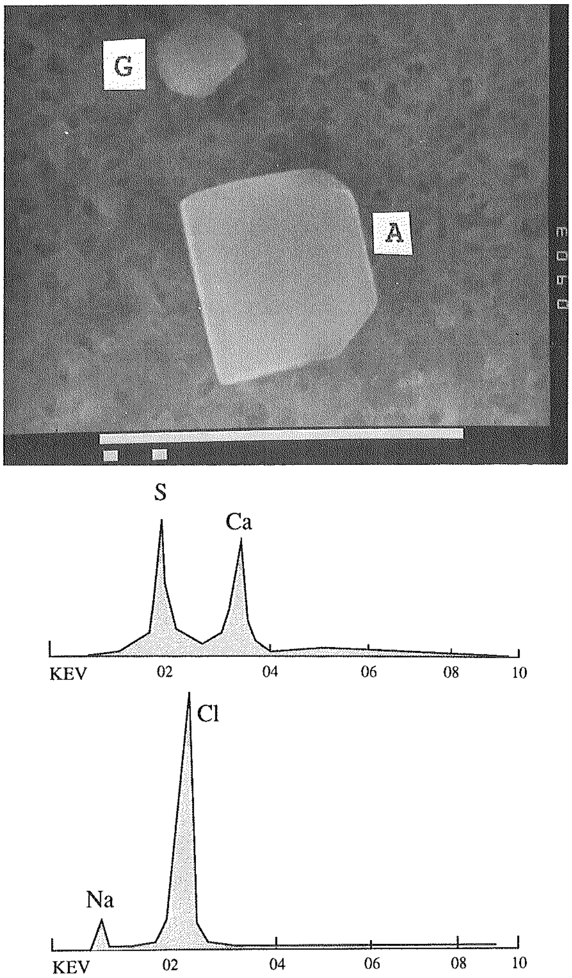


Fig. 7. Photograph of the SEM image. (A) a sea salt particle ; (G) a gypsum particle with spectra. (scale ; 10 $\mu$m)

small sea salt particles. On the other hand, there are also the particles which consist of a large sea salt particle and small soil particles. Figure 10 is a SEM image of a mixed particle which is based on a large sea salt particle. The large particle appears to be NaCl, showing a flat crystal surface, while the small soil particle has an irregular shape. One fact which is common to both types is that the size of the large particle is several microns (a particle classified as a giant particle) and that of the small particle is a submicron (classified as a large

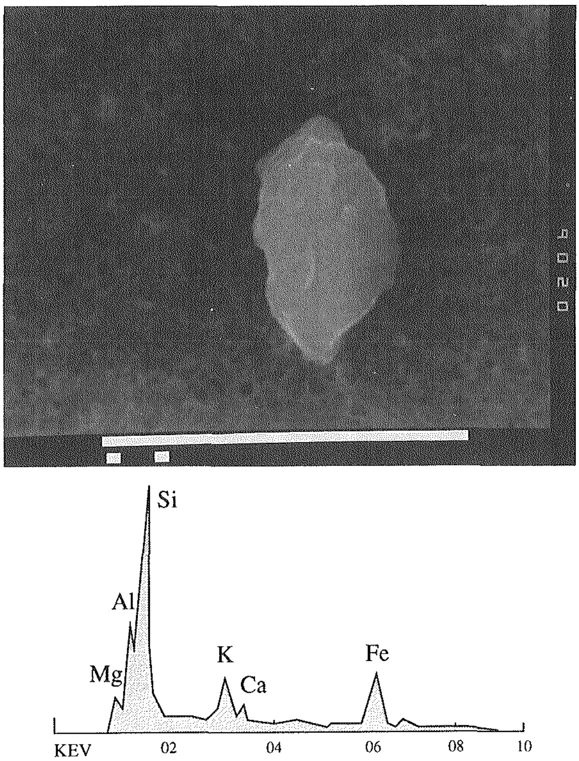


Fig. 8. Photograph of a soil particle and its spectra of elements. (scale ; 10 $\mu$m)

particle) ; that is, the difference in size between large and small particles reaches about one order.

It has been found from these facts that collision and coagulation in air takes place between these particles of which the size difference is one order.

Table 2 shows the classification and the number of the aerosol particles. It is seen in the table that 37.9% of the total number is soil particle, 27.7% sea salt particles, and 20.8% other particles which were not detected as soil or sea salt particles by the EDX system. 13.5% of the total number are counted as mixed particles.

Moreover, the number of particles is classified in the Table 2 into large particles ($r \leqq 1$ $\mu$m) and giant particles ($r > 1$ $\mu$m). As mentioned in section 3.2, the number of the particles $\leqq 1$ $\mu$m analyzed are few, while the frequency of mixed particles in number is also small in comparison with that of the giant particles. On the other hand, the frequencies of large and giant particles are almost the same with both soil and sea salt particles. Therefore, mixed

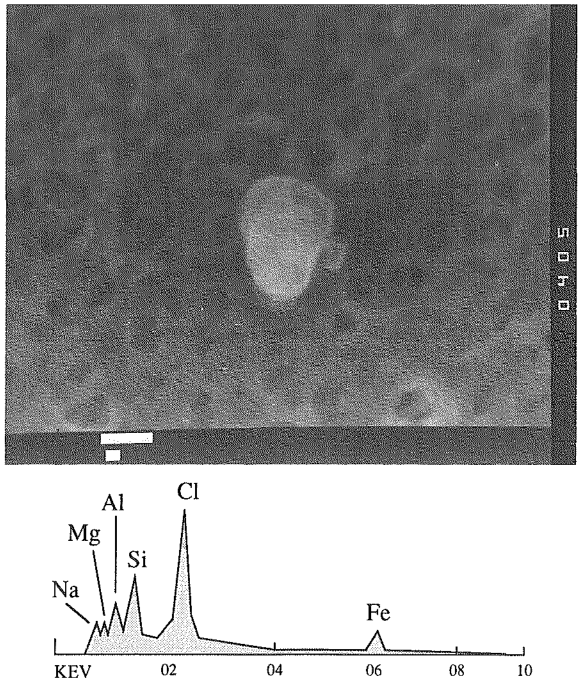


Fig. 9. Photograph of mixed particle consisting of a large soil particle with small sea salt particle and the spectra of elements. (scale ; 1 $\mu$m)

particles may be produced as a giant particle.

## 4. Conclusions

Aerosol particles were collected at Rumoi, Hokkaido during the spring of 1995 and 1996 and were analyzed by the SEM-EDX system relative to their size, shape and elemental composition. Moreover, the trajectories of the air masses containing aerosol particles were described. From the analysis supplied above, the following results have been obtained :

1) Soil particles collected at Rumoi were generated in the northern part of China and Mongolia, which is an arid area of the Asian continent.

2) Sea salt particles produced on the sea surface were added to the air mass as it moved over the Japan Sea.

3) Mixed particles were made by the collision of giant particles $>1$ $\mu$m with large particle $\leqq 1$ $\mu$m.

4) Mixed particles made up 13.5% of the total number of particles analyzed

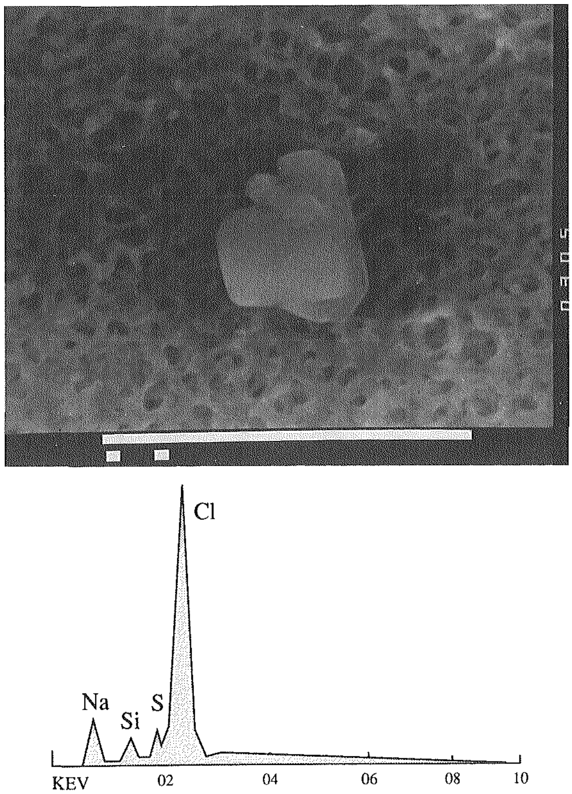


Fig. 10. Photograph of a mixed particle consisting of a large sea salt particle with small soil particle and the spectra of elements. (scale ; 10 $\mu$m)

Table 2. Numbers of soil, sea salt and mixed particles

| | Number | Soil | Sea salt | Mixed | Other |
|---|---|---|---|---|---|
| Large particle (r≦1.0 um) | 127 | 50 (39.4%) | 36 (28.3%) | 6 (4.7%) | 35 (27.6%) |
| Giant particle (r>1.0 um) | 992 | 348 (37.7%) | 255 (27.7%) | 136 (14.8%) | 183 (19.8%) |
| Total | 1,049 | 398 (37.9%) | 291 (27.7%) | 142 (13.5%) | 218 (20.8%) |

by the SEM-EDX system.

It is concluded from the facts provided above that the mixed particles are water-soluble, and that there are a number of nuclei sufficient for the cloud droplets and ice crystals to be produced in snow clouds.

## Acknowledgments

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