Pergamon

Atmospheric Environment Vol. 30, No. 2, pp. 347–351, 1996
Elsevier Science Ltd
Printed in Great Britain
1352-2310/96 $9.50 + 0.00

1352–2310(95)00271–5

SHORT COMMUNICATION

MINERAL PARTICLES COLLECTED IN CHINA AND JAPAN DURING THE SAME ASIAN DUST-STORM EVENT

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(*First received* 7 *July* 1994 *and in final form* 28 *June* 1995)

Abstract—Aerosol particles were collected at China and Japan in the same spring Asian dust-storm event of 1991 in order to study the change in composition of mineral aerosol particles during long range transport. It was found on the basis of a microchemical analysis that dust particles containing Mg, Al, Si, K, Ca and Fe were a major fraction of the aerosol particles collected at Hohhot and Beijing, China, and Nagasaki, Japan. A large fraction of the mineral aerosol particles was internally mixed with sea salt in Nagasaki. Present study suggests that the internal mixed particles were mainly produced by cloud processes through droplet coalescence.

Key word index: Asian dust-storm particles, X-ray spectrometry, long-range transport (LRT).

1. INTRODUCTION

Asian dust-storm particles originate in northwest and north China by frontal activities in spring and there can be a fairly widespread transport of these particles over northern China as well as Japan, even in remote oceanic regions. They constitute a considerable fraction of soil derived aerosols over the Japanese islands (Kadowaki, 1979; Ishizaka and Ono, 1982; Arao and Ishizaka, 1986) and also contribute most of the sedimentation material in the North Pacific Ocean floor (Duce *et al.*, 1980; Uematsu *et al.*, 1983) in spring time. Hence, increasing attention has been devoted to the study of physicochemical characteristic change of Asian dust-storm particles during long-range transport (LRT).

Analyses of the individual Asian dust-storm aerosol particles have been carried out by several researchers. They have reported the presence of Asian dust-storm particles containing sea salt in the atmosphere over the Japanese islands and the North Pacific Ocean (Okada *et al.*, 1990) and over the western Pacific Ocean (Zhou *et al.*, 1992). However, our knowledge of the properties of Asian dust-storm particles is far from complete. Especially, there is no research about the individual aerosol particle which collected over China and Japan in the same Asian dust-storm event so as to understand the variability during transport processes.

The purpose of this paper is to report the composition of individual Asian dust-storm particles collected over China (Hohhot and Beijing) and Japan (Nagasaki) in the same spring Asian dust-storm event of 1991 and to examine the modification of the dust particles during LRT.

2. SAMPLING AND ANALYSIS PROCEDURES

Collections of aerosol particles were carried out in Hohhot (00:02–00:12 GMT 29 April), Beijing (10:13–10:23 GMT 30 April) and Nagasaki (07:49–07:59 GMT 1 May) during the Asian dust-storm episode of 1991. The sampling sites and the weather condition of the period are shown in Fig. 1. Aerosol particles were collected directly on a carbon-covered nitrocellulose (collodion) film supported on an electron-microscopic grid by using an impactor of 1-mm diameter jet with an air flow rate of $1.3\ \ell\ \mathrm{min}^{-1}$.

The samples were coated with a vapor-deposited thin film of Pt/Pd alloy with a shadowing angle of arctan 0.5 in order to investigate the shape and volume of individual particles. An electron microscope (Hitachi, H-600 and H-6010) was used for examining the size and morphology. And the X-ray spectrum from the center of an individual particle has been obtained from an energy-dispersive X-ray analyzer (Kevex, delta V) with a Kevex UTW (ultra thin window) detector attached to the microscope.

Number of mineral particles examined here are 95, 95 and 66 in the samples collected in Hohhot, Beijing and Nagasaki, respectively. Most of the particles analyzed had radii of 1–2 μm.

3. RESULTS

This dust-storm originated near Ulaan baatar (Fig. 1) and it was triggered by the strong wind behind the cold front

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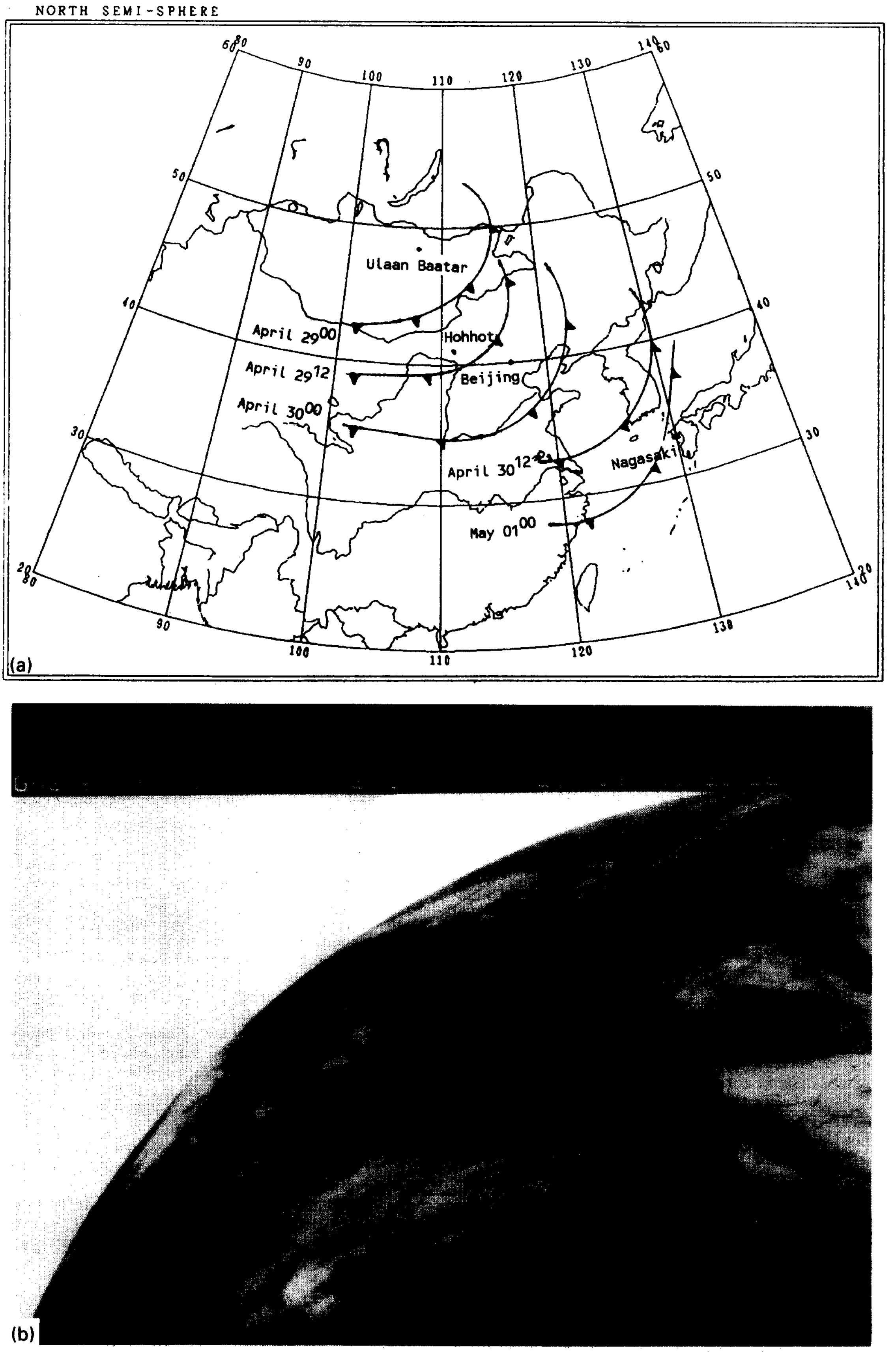


Fig. 1. Weather condition during the period of the spring 1991 Asian dust-storm event. (a) The moving path of the surface cold front during 29 April to 1 May. (b) The GMS image at 23:32 GMT on 30 April.

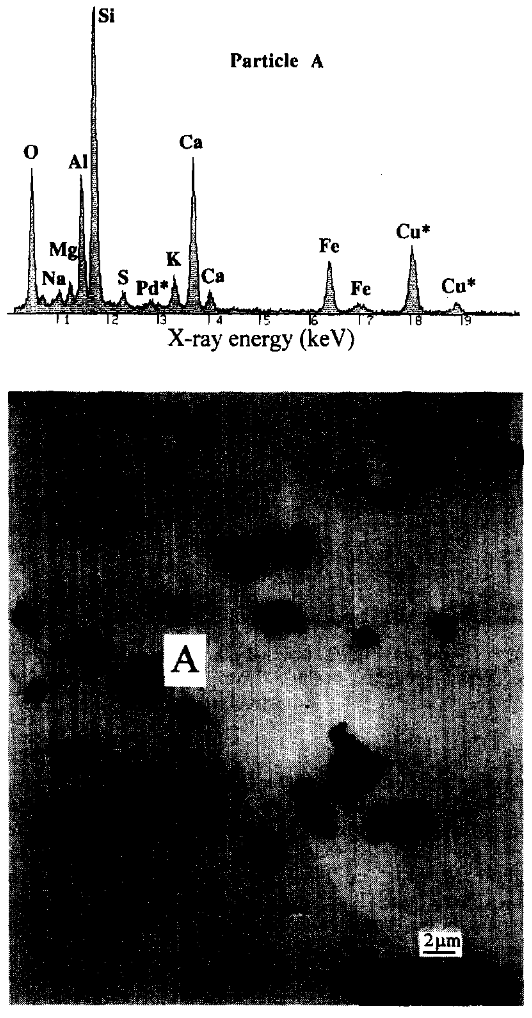


Fig. 2. Electron micrograph of individual particles collected in Hohhot on 29 April and the X-ray spectra obtained from particles A. The Cu peaks in the spectrum originated from the copper grid used in the examination. The Pd peak is due to the Pt/Pd alloy used for shadowing.

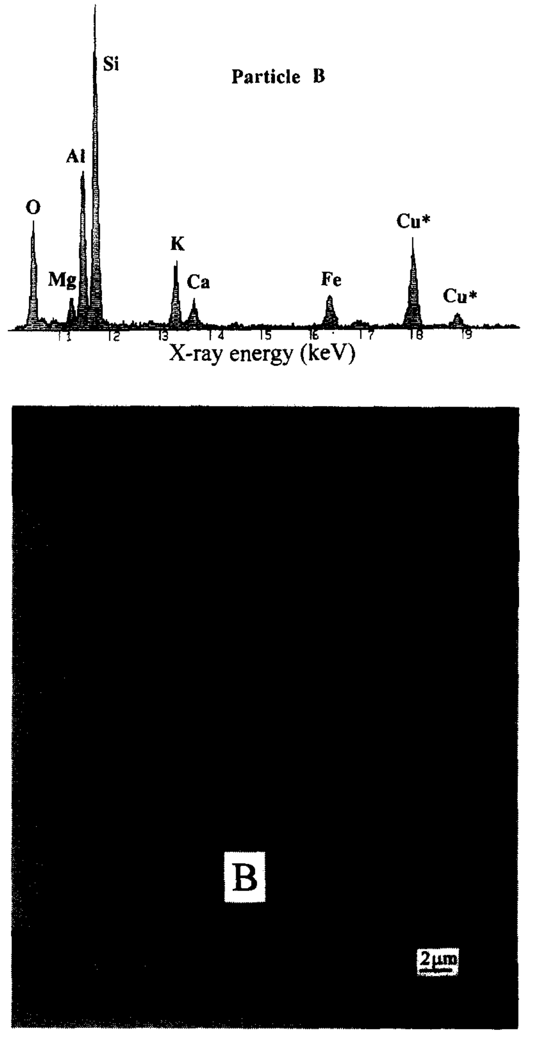


Fig. 3. Same as Fig. 2, but for Beijing on 30 April and the X-ray spectra of particle B.

from the north. There was strong ascending air in the Hunshandake sandy land area (Center: 43°N, 115°E) and it might have affected this storm (Sheng *et al.* 1994).

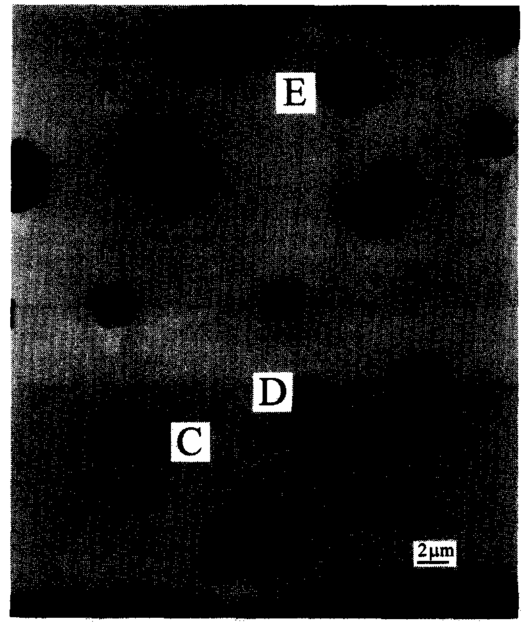
Figure 2 shows an electron micrograph of particles collected in Hohhot, together with X-ray spectra from the center of particle A. The X-ray spectrum shows clearly the dominant peaks of Mg, Al, Si, S, K, Ca and Fe. The frequencies of Mg, Al, Si, Ca, Fe in the mineral particles collected in Hohhot on 29 April are $\geqslant 77\%$. The frequencies of S, Na and Cl are 42%, 13% and 0%, respectively.

The electron micrograph of particles collected in Beijing is shown in Fig. 3, together with X-ray spectra from particle B. The particle is composed of electron-dense material with an irregular shape. The X-ray spectrum shows clearly the dominant peaks of Mg, Al, Si, K, Ca and Fe. A peak of O shows that these elements are present as oxides. Electron-dense particles containing Al and Si are determined to be minerals. Desert and loess soil particles from China contain $CaCO_3$ with a high weight fraction (Hseung and Jackson, 1952) and soil in Japan contains very small amount of Ca (Tanaka *et al.*, 1986). Since Ca is detected, this mineral particle is considered to be an Asian dust-storm particle. Mineral particles collected in Beijing on 30 April contain Mg, K, Ca, Fe at frequencies of $\geqslant 62\%$. S, Na and Cl are detected in 14%, 10% and 0% of mineral particles. The same situation as Hohhot, Na would be originating from soil, not sea salt. Note that Cl is not present.

Figure 4 shows an electron micrograph of particles collected in Nagasaki and the X-ray spectra obtained from the particles C, D and E. The X-ray spectrum from particle C shows strong peaks of Na and Cl, indicating that this particle is sea salt. Whereas, sea salt particles are not found in Hohhot and Beijing. Particle D contains Mg, Al, Si, Ca and Fe, and particle E also contains mineral elements of Al, Si, and Fe. From X-ray spectrum of particle E, it can be found that the mineral particle contains sea-salt elements of Na and Cl. A lot of similar mixed particles are detected in the sample collected in Nagasaki. Although irregular-shaped mineral particles are found in Fig. 4, some of them are surrounded by liquid-like material (i.e. particle E). Mineral particles in Nagasaki on 1 May contain Mg, K, Ca, Fe at frequencies of $\geqslant 45\%$. Na and Cl occur in high frequencies, $\geqslant 58\%$. Note that about 20% of all the aerosol particles in the sample collected in Nagasaki are sea-salt particles which are present externally with minerals.

Andreae *et al.* (1986) reported that a large fraction of dust particles was found to be internally mixed with sea salt over the Equatorial Pacific Ocean and Parungo *et al.* (1986) found that a lot of Sahara dust particles were also mixed internally with sea salt over the Atlantic Ocean. Asian dust-storm particles mixed internally with sea salt were determined by the following criterion (Niimura *et al.*, 1994): (1) presence of both Na and Cl, and (2) Na/Si weight ratio $\geqslant 0.25$ even if Cl was not detected in mineral particles. It was found on the basis of analysis that a large fraction (60%) of the mineral particles collected at Nagasaki was internally mixed with sea salt but there was no mixed particle detected in Hohhot and Beijing. It follows that the accumulation of the sea-salt component on individual dust particles would have occurred during the transport over the marine atmosphere between China and Japan.

In the cloud-free atmosphere, the conglomeration of dust particles with sea-salt particles will not occur through Brownian coagulation and impaction by differential sedimentation during the short transport time of 1–2 d. From the images obtained by the Geostationary Meteorological Satellite (Fig. 1b), many convective clouds (< 6 km altitude) came out over the marine boundary layer during the Asian dust-storm event so that the mineral particles



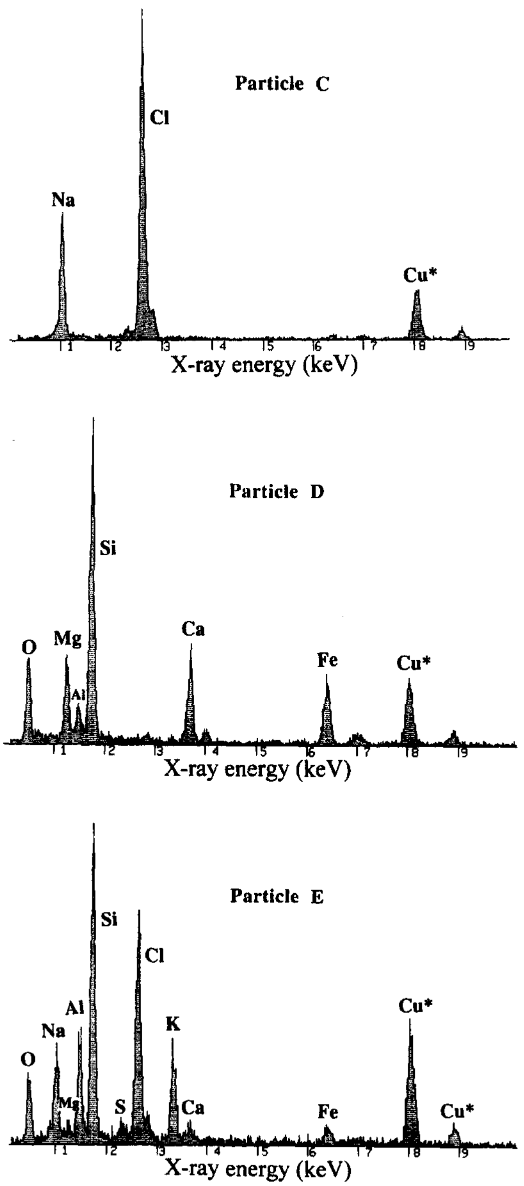


Fig. 4. Same as Fig. 2, but for Nagasaki on 1 May and the X-ray spectra obtained from particles C,D and E, respectively.

stayed in the cloudy atmosphere for a long time. As stated by Okada *et al.* (1990), the dust-storm particles often contain a small amount of water-soluble material. Therefore, the dust particles with radii of about 1 μm should act as cloud condensation nuclei (CCN) in the atmosphere with low supersaturation because of large particle radius. When the continental air enters the marine boundary layer in which sea-salt particles are present abundantly, both dust and sea-salt particles would act as CCN. It was easy to form cloud dorplets individually on dust and sea-salt particles in clouds. Coalescence of these droplets will occur and internal mixture of dust particles with sea salt will then be formed upon the evaporation of the cloud droplets.

4. CONCLUSION

Dust particles were collected in Hohhot and Beijing (China) and Nagasaki (Japan) during the same Asian dust-storm event in the spring of 1991. The collected samples were examined using an energy-dispersive X-ray analyzer equipped with an electron microscope. Although dust particles were composed of electron dense material with irregular shape, some of the particles collected in Nagasaki were surrounded by liquid-like material. The X-ray analyses showed the presence of sea salt in individual dust-storm particles in Nagasaki. The proportion of dust particles internally mixed with sea salt was 60% on 1 May in Nagasaki. It is suggested that cloud processes during the transport paths are important in the formation of dust particles internally mixed with sea salt, and the conglomeration of dust-storm particles with sea salt forms larger hygroscopic particles.

Acknowledgements—This study was performed mainly in the HEIFE project, a coorperative research supported jointly by the National Natural Science Foundation of China, Chinese Academy of Science, China, and the Japanese Ministry of Education, Science and Culture, Japan.

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