Atmospheric Environment in East Asia : Importance of the Japan Sea

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Atmospheric Environment in East Asia: Importance of the Japan Sea

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Abstract - Westerly wind is predominant over East Asia and West Pacific regions, and various atmospheric constituents including natural and anthropogenic origin are transported from the Asian continent to the Pacific ocean by the westerly. Dust particles emitted from the arid regions of China strongly suggested chemical-physical transformations during the long-range transformation of dust particles. Existence of Japan sea possibly activates those transformation..

I. Introduction

Recently many investigations on Asian continental particulate, especially Asian dust particles (KOSA particles, KOSA leterally means yellow sand in Japanese), were made by a lidar [4, 7, 13], a satellite [2], a Sun photometer [8, 9], and ground-based sampling of particulates [10, 11, 12, 18, 19], and numerical model [1] since KOSA particles become great concern from view point of radiative effect of KOSA particles and KOSA particle contribution to geochemical cycle of atmospheric constituents in the east Asia and west Pacific regions.

Long-range transport of KOSA particles, therefore, becomes a matter of great concern and many campaigns such as ACE-Asia including various type of field observations have been conducted. Many lidar measurements made in Japan suggested that long-range transport of KOSA particles was extremely active in the free troposphere over east Asia and west Pacific regions in spring [3, 4, 6,12], and Taklamakan desert is suggested as possible strong source of KOSA. Some investigators suggested that weak KOSA events which were so small that we could not detect near the ground, in addition to severe KOSA events, made possible contribution of geochemical cycle of minerals. Aircraft-borne measurements also confirmed effect of weak KOSA events on chemical composition of particulate matter in the free troposphere over Japan [6].

However there, concerning with nature of dust particles in the free troposphere over the desert areas of the Asian continent in summer, are little information have been suggested.

Here we present results of field observations made with electron microscopic experiments of particles collected with the balloon-borne particle impactor, balloon-borne optical particle impactor and lidar in the free troposphere in 2001 and 2002 at Dunhuang (40°00'N, 94°30'E), China which is in east side of Taklamakan desert and discuss importance of geographical situation of east Asia regions which seems to be essential factor causing chemical-physical transformation of dust particle dust particles in the summer free troposphere.

II. Measurements and Results

It has been well known that severe Kosa events appear associating with cold fronts activities of low pressure system over Japan, and satellite cloud image clearly shows that relations. However many lidar measurements suggested that dust particles frequently diffuse in the free troposphere over Japan even when low pressure activities were not observed, and Iwasaka et al. [3] called such type Kosa episode 'weak Kosa'. Meteorological analysis suggested that there was large possibility of long range transport of dust particles in the free troposphere of about 4-6 km over east Asia and west Pacific regions, and confirmed tropospheric diffusion of dust particles (Merrill et al. 1989, not cited).

Direct aerosol particles were tried with balloon-borne and aircraft-borne particle impactor to make chemical analysis and/or electrom microscopic experiment of particulate matter in the free troposphere. In the aircraft-borne measurements Iwasaka et al. [3] suggested the possibility of chemical transformation of dust particles through surface chemical reactions during long-range transport. Mori et al. [6] suggested, on the basis of chemical analysis of particulate matter collected in the free troposphere, the possibility that Kosa particles frequently observed in the free troposphere over Japan even when Kosa event was not detected near the ground. Recently electron microscopic experiments of particles collected in the free troposphere over Japan clearly indicated sulfur deposition on Kosa particles [5, 16]. Sampling of particulate matter was tried on the summit of high mountains to know chemical compositions of free tropospheric particles (Kid et al. 2000, not cited).

However, there were few observations on physical and chemical properties of atmospheric particles over the arid areas in China even though they have been believed to be Kosa source regions. Atmospheric science research team of Nagoya University made intensive measurements on aerosol concentration, size, shape, and chemical composition with balloon-borne optical particle counter, balloon-borne particle impactors, and ground-based lidar at Dunhuang (40°00'N, 94°30'E), China to know feature of aerosols over the Taklamakan desert areas (Fig. 1).

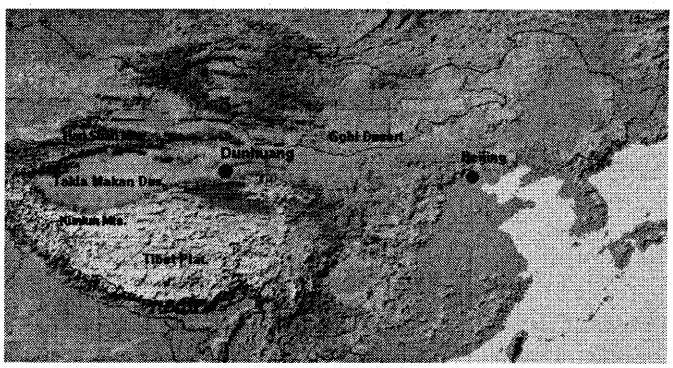

Fig.1. Sampling location, Dunhuang, China.

In Fig. 2 (A) typical example of SEM image and EDX spectrum of coarse particles collected in heights of 3km – 5km. Particle (a) is the example showing only Ca peak (Ca dominant) EDX spectrum, and very similar spectrum was obtained by Okada and Kai [11] and Zhou et al. (1996, not cited) who suggested that this kind of spectrum indicated main composition of particle to be calcite ($CaCO_3$). The EDX spectrum of particle (b) is the example showing Na peak, and halite (NaCl) and thenardite (Na_2SO_4) are suggested as main candidate composition. Typical NaCl particles frequently have cubic shape and show Na and Cl peak in EDX spectrum. No strong peak of Cl was found in the spectrum of particle (b) and peak of sulfur was identified. It is, therefore, possibly suggested that the Na-dominant particles (b) is mainly composed of thenardite (Na_2SO_4). Particle (c) showed irregular shape and EDX spectrum showed noticeable peak of Al and Si (Si + Al particle). Simillar spectrum, sometimes along with peaks of Mg, K, Ca, and Fe, was frequently identified from the particles containing alluminocilicate collected in the ground atmosphere over desert areas in China [11], in the ground atmosphere at Beijing during severe Kosa event [(Zhou et al. 1996, not cited), 18 19,], and in the free atmosphere over Japan during weak Kosa event [16]. It is reasonable to assume, considering those previous observations even though those were based on particle collection in the ground atmosphere without Trochkine et al. [16], that particle (c) in Fig. 2 (A) is composed of alminocilicate.

Most of fine particles, as shown in Table I, contained sulfur, and ratio of S-rich particles to total fine particles was about 90% (3-5km), 84% (5-7km), and 91% (7-8km). Additionally S-dominant particles were major of S-rich particles (more than 95% in all heights regions). Therefore it is suggested that S-dominant particle is major of fine particles in the free troposphere. Typical SEM image and EDX spectrum of those particles are shown in Fig. 2 (B).

From lidar measurements, scattring ratio (values of [scattering ratio – 1] are corresponding to mixing ratio of particulate matter) and depolarization ratio (values are corresponding to nonspherisity of particles) are obtained. Fig. 3 shows depolarization ratio deduced from the lidar measurements which was performed corresponding to the balloon-borne experiment at Dunhuang, Chian. The large depolarization values suggested that nonspherical particles, possibly dust particles having usually irregular shapes, diffused from near the boundary to about 6km height. This observational fact shows good agreement with the evidence that dust particles are identified in the free troposphere by electron microscopic (SEM-EDX) experiments. It should be noted that the Kosa layer found in Japan has layered structure with peak height in 4-7km and thickness of 0.5km-2.0km, but both scattering ratio and depolarization ratio obtained at Dunhuang showed largely different vertical profiles, especially large deporalization ratio distributed from near the ground to about 5km.

Comparing with the chemical element distribution obtained at Dunhuang (Table I) and those at Japan t is easily suggested that dust particles collected over Japan were enriched by sulfur. One of possible explanations is deposition of anthropogenic sulfur on the surface of Kosa particles during particle long-range transport.

Wetting on Kosa particle surface, as suggested by Iwasaka et al. [3], seems to be important factor activating surface reactions. The surface reactions affect various processes: sulfur budget, nitrogen budget, and acidity of rain (Carmichael et al. 2002, not cited). Most of air masses are usually modified by large source of water vapor during their traverse over the Japan sea, and the surface of the aerosols including in the air masses are activated under atmospheric condition of relatively high humidity. Therefore, it is interesting to search out effect of air masses modification by the Japan sea on global and/or regional climate and environment.

III. Summary and Conclusion

Measurements made at Dunhuang, China suggested followings;

(1) atmospheric mineral aerosols (Kosa particles) over Taklamakan
desert areas possibly have clean surface.

(2) comparison of chemical element of particles collected in the free troposphere over Taklamakan desert and over Japan suggested possible effect of sulfur deposit on Kosa particle surface.

(3) Japan sea has large potential activating the surface reaction.

(4) consequently Japan sea has large potential long range transport of sulfate, sulfate deposition, sulfate particle formation and diffusion, radiative effect of Kosa and sulfate particles.

Potential contribution of Japan sea on global/regional climate and environment has not been fully understood. Intensive and integrated research is desired concerning with relationship between long range transport of Kosa particles and chemical-physical modification over the Japan sea.

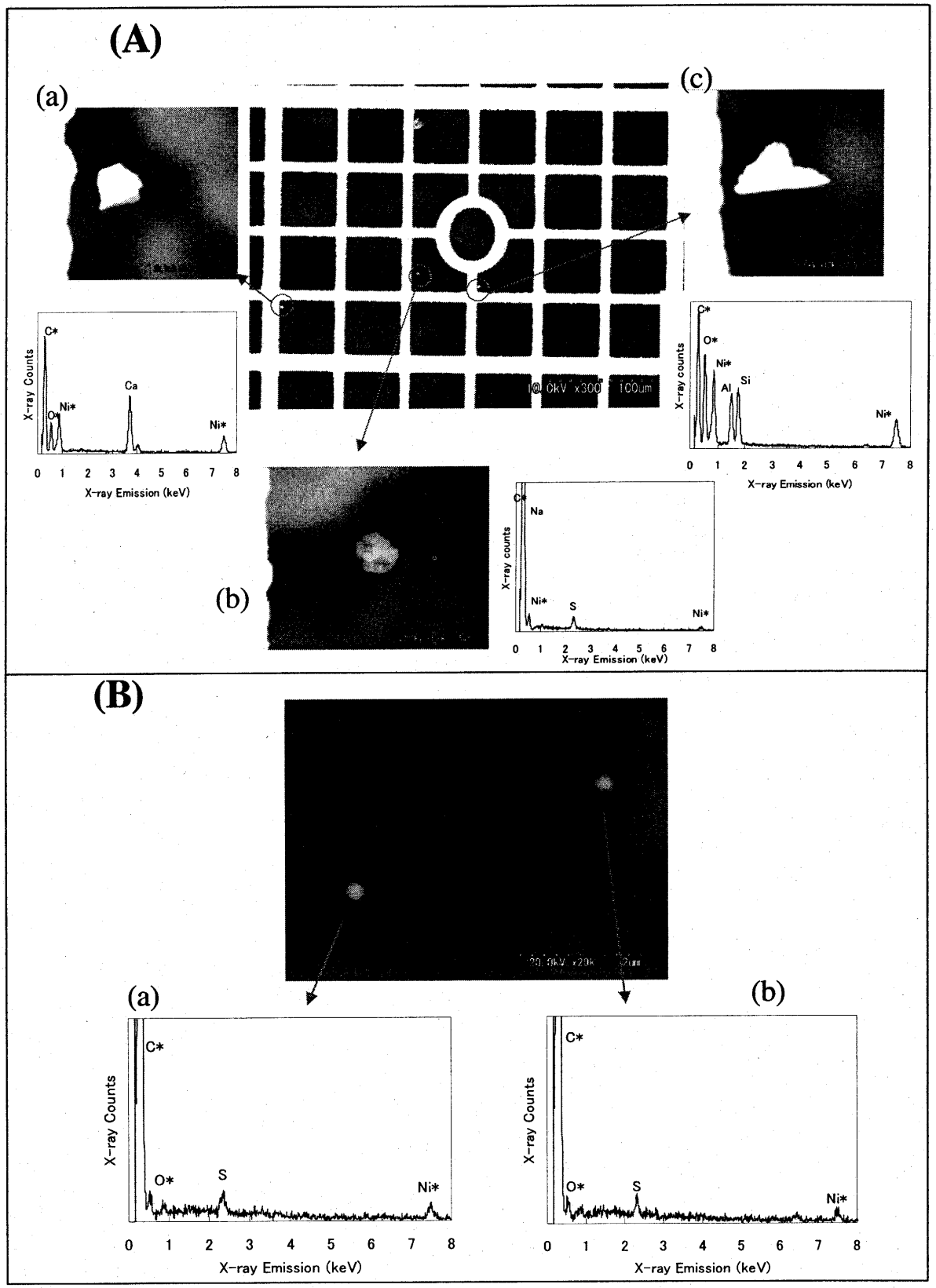

Fig. 2. Electron micrograph of individual particles collected in the free troposphere between about 3km and 5km over Dunhuang, China.
(A) Coarse particles (a), (b) and (c) is calcite ($CaCO_3$), thenardite (Na_2SO_4) and aluminosilicate, respectively. And, both fine particles (d) and (e) aer ammonium sulfate.
(B) Both fine particles (a) and (b) are ammonium sulfate.

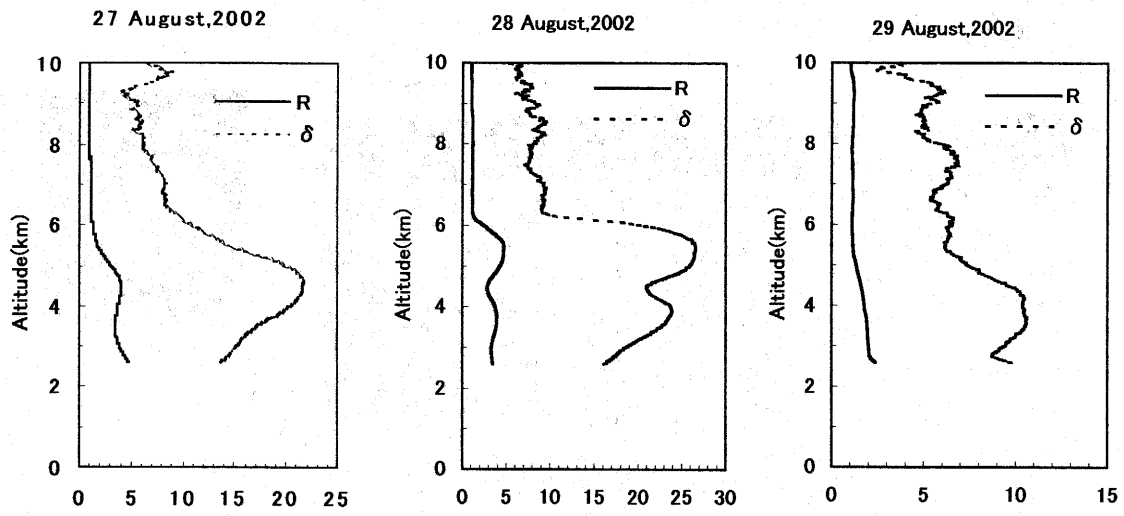

Fig. 3. Lidar return: Scattering ratio corresponding aerosol mixing ratio (——), and depolarization ratio indicating nonspherisity of particles (------) observed at Dunhuang, China Definitive scattering ratio and depolarization ratio are followed by Kwon et al. [4].

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Table I
Conbination of chemical elements of the collected particles during the balloon-borne measurements.

coarse particles	3-5km	5-7km	7-8km
Na-rich	**6**	**0**	**0**
Na-dominant	1	0	0
Na+S	2	0	0
Na+Mg+S+Ca	1	0	0
Na+S+Ca	1	0	0
Na+S+As	1	0	0
Si-rich	**16**	**1**	**1**
Si-dominant	4	0	1
Si+Al	2	0	0
Si+Al+Fe	2	0	0
Si+Al+Fe+Mg	3	0	0
Si+Mg+Al	0	1	0
Si+Ca+Fe	1	0	0
Si+Al+K	1	0	0
Si+Na+Al	1	0	0
Si+Ai+As	1	0	0
Si+Na+Mg+Al+Fe	1	0	0
Ca-rich	**16**	**1**	**3**
Ca-dominant	7	0	0
Ca+S	3	0	2
Ca+Mg	1	0	0
Ca+Si	3	1	1
Ca+Mg+Si	1	0	0
Ca+Zr	1	0	0
S-rich	**4**	**0**	**0**
S-dominant	3	0	0
S+Na	1	0	0
Fe-rich	**0**	**0**	**1**
Fe-dominant	0	0	1
Zn-rich	**2**	**0**	**0**
Zn+Cl	2	0	0
Mg-rich	**1**	**0**	**0**
Mg+Ca	1	0	0
Total number of particle examined	**45**	**2**	**5**

fine particles	3-5km	5-7km	7-8km
Si-rich	**1**	**2**	**2**
Si-dominant	0	0	2
Si+Mg+Al+Fe	1	0	0
Si+Al+K	0	1	0
Si+Mg+Al	0	1	0
Ca-rich	**1**	**4**	**1**
Ca-dominant	0	1	0
Ca+S	0	3	0
Ca+Si	1	0	1
S-rich	**49**	**31**	**32**
S-dominant	47	30	31
S+Si	1	0	0
S+Na+K	0	1	0
S+Zn	0	0	1
S+K	1	0	0
K-rich	**3**	**0**	**0**
K+S	3	0	0
Total number of particle examined	**54**	**37**	**35**