Elemental components and maps of fine sand in Taklimakan Desert

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ABSTRACT

PIXE analysis of a fine sand sample from the Taklimakan Desert revealed 20 elements, of which Na, Mg, Al, Si, Cl, K, Ca, Ti and Fe were found to be the major components. Comparing the determined values of the fine sand sample with determined values of China Loess (CJ-1) and Simulated Asian Mineral Dust (CJ-2), the concentration level (except for Cl) were similar, and Cl was 10 and/or 5 fold. Therefore, fine sand from the Taklimakan Desert was assumed to be the origin of the loess and Aeolian dust transported to Japan. Maps of Al, Si, K and Fe were very similar, but the Ca map was close to the STIM image of the high-energy window, indicating that Ca was likely in relatively large particles.

Key words: Taklimakan Desert, Fine sand, Multi-elemental analysis, PIXE, Micro-PIXE

1.   INTRODUCTION

Aeolian dust (mineral dust) from the arid inland parts of central Asia carried by the prevailing westerlies is often observed in Japan during the spring. It is known as a Kosa event, and in Japan this Aeolian dust is called "Kosa aerosol." In atmospheric environmental studies of global climate and geochemical mass cycles, Kosa aerosol is a very important source of the soil-derived component of atmospheric aerosol. Therefore, many researchers focus on climate impact and long-range transport of the dust [1-3]. Naturally, Kosa aerosols have been observed in various locations in China, Korea, Japan and the Pacific Ocean by aerosol monitoring, and aerosols collected at these locations have been chemically analysed [4-6]. However, there are few reports on chemical components in fine sand from deserts in central Asia that are the source of Kosa aerosol [7,8]. Chemical component data of the fine sand from deserts are important when evaluating the contribution of Kosa aerosols to the collected aerosols. Consequently, we analyzed elemental components of fine sand from the Taklimakan Desert by PIXE and their elemental maps by micro-PIXE.

2.   EXPERIMENTAL AND METHODS

Sampling of fine sand in the Taklimakan Desert was carried out at Kijiru-senbutsudo (41° 42' N, 82° 02' E), China, in September 2002. Results of the analysis of size distribution of the fine sand using a Laser Scattering Particle Size Distribution Analyzer (HORIBA LA-910) showed that the median size was 13 μm and that 37% had a diameter <10 μm. To evaluate the elemental components of the fine sand, elemental analysis of China Loess (CJ-1) and Simulated Asian Mineral Dust (CJ-2), which are certified reference materials prepared by the National Research Center for Environmental Analysis and Measurement (China) and the National Institute for Environmental Studies (Japan), respectively, was also performed. CJ-1 was collected from the loess layer in Gunsu Province of China, and the origin of CJ-2 was the southwest part of the Tengger Desert in Ning Xia Hui autonomous region of China.

For elemental component analysis, the fine sand, CJ-1 and CJ-2 samples were prepared using the method developed by Sera and Futatsugawa [9], where 200 mg of the samples were ground into fine powder in

an agate mortar, and palladium-carbon powder (5% Pd) was added as an internal standard in an amount of 40 mg, after which they were mixed uniformly in the agate mortar. The thinnest target was prepared by taking ≈0.1 mg of the powder and putting it onto a 4 μm-thick polypropylene film, and dropping roughly 1 μl of 10% collodion solution diluted with ethyl alcohol onto it for fixing and smoothing. This process was carried out in a clean-bench. Five such thin targets were prepared for each sample in order to confirm reproducibility. Elemental concentrations were determined by PIXE at Nishina Memorial Cyclotron Center, Japan Radioisotope Association. The thinnest target was used for PIXE analysis. It was bombarded with 2.9 MeV protons from a small-size cyclotron [10]. Beam currents, the accumulated charge and the typical measuring time were 2-3 nA, 2-3 μC and 10-16 minutes, respectively. X-ray spectra were analyzed using the SAPIX program [10]. Quantitative analysis of elemental concentrations was performed based on a powdered internal standard method [9]. The accuracy of the PIXE analysis was confirmed by analysis using NIST standards [11].

For elemental maps, the target sample was prepared by taking ≈1 μg of the fine sand sample and putting it onto a sample holder equipped with a 4 μm-thick polypropylene film, and dropping roughly 1 μl of 10% collodion solution diluted with ethyl alcohol onto it for fixing and smoothing. This process was carried out in a clean-bench. A scanning transmission ion microscopy (STIM) image and elemental maps of the target sample were analyzed by micro-PIXE at the National Institute of Radiological Sciences [12]. The proton beam energy was 2.6 MeV and total accumulated charge was 10 nC. The scanning area of the micro-beam was 200 × 200 μm and 100 × 100 μm, and the spatial resolution of the micro-beam was about 1 μm or less. X-ray spectra were analyzed using the OM_DAQ data acquisition system [13]. The number of target elements was 18: Na, Mg, Al, Si, S, Cl, K, Ca, Ti, Cr, Mn, Fe, Ni, Cu, Zn, Sr, Zr and Pb.

3. RESULTS AND DISCUSSIONS

In PIXE analysis of the fine sand sample, 20 elements were determined, and Na, Mg, Al, Si, Cl, K, Ca, Ti and Fe were the major components. Table 1 shows the arithmetic mean concentration and standard deviation of the fine sand. Comparing the arithmetic mean shown in Table 1 with determined values of CJ-1 and CJ-2, the concentration level (except for Cl) were similar, and Cl was 10 and/or 5 fold. Therefore, fine sand from the Taklimakan Desert was assumed to be the origin of the loess and Aeolian dust transported to Japan.

TABLE 1. Values determined by PIXE for a fine sand sample from the Taklimakan Desert.[1]

Element	Mean ± SD	Element	Mean ± SD	Element	Mean ± SD
Na (%)	0.375 ± 0.035	Ca (%)	5.89 ± 0.09	Zn (μg/g)	59.8 ± 5.2
Mg (%)	0.461 ± 0.055	Ti (%)	0.192 ± 0.018	Br (μg/g)	14.2 ± 3.5
Al (%)	2.45 ± 0.31	Cr (μg/g)	51.6 ± 2.1	Rb (μg/g)	72.8 ± 5.3
Si (%)	12.2 ± 1.29	Mn (μg/g)	548 ± 7	Sr (μg/g)	256 ± 25
S (μg/g)	418 ± 40	Fe (%)	2.13 ± 0.22	Hg (μg/g)	32.8 ± 5.4
Cl (%)	0.349 ± 0.025	Ni (μg/g)	32.3 ± 6.5	Pb (μg/g)	43.4 ± 4.6
K (%)	1.04 ± 0.08	Cu (μg/g)	20.6 ± 3.4		

*[1]: Mean and SD of five measurements.

Of the 18 elements targeted for elemental analysis by micro-PIXE, 11 were detected in the fine sand sample. The elements not detected were Na, Ni, Cu, Zn, Sr, Zr and Pb. We were able to create a real image in the form of an elemental map for five (Al, Si, K, Ca and Fe) detected elements. Shown in Figure 1 are elemental maps and a STIM image. A STIM image is an image of protons transmitted through a sample in which energy loss of transmitted ions depends on thickness and density, and creation of the image relies heavily on the setting of the region of interest (ROI). From the transmission energy spectrum information obtained by STIM, ROI is put in three divisions—ROI-1 (low-energy window, 5 – 30%), ROI-2 (middle-energy window, 36 – 42%) and ROI-3 (high-energy window, 43 – 46%)—to determine those ROI. On the STIM image of middle-energy and high-energy windows, thick or dense

particles were imaged, and they were especially clear in the middle-energy window. Maps of Al, Si, K and Fe were very similar, but the Ca map was close to the STIM image of the high-energy window, indicating that Ca was likely in relatively large particles.
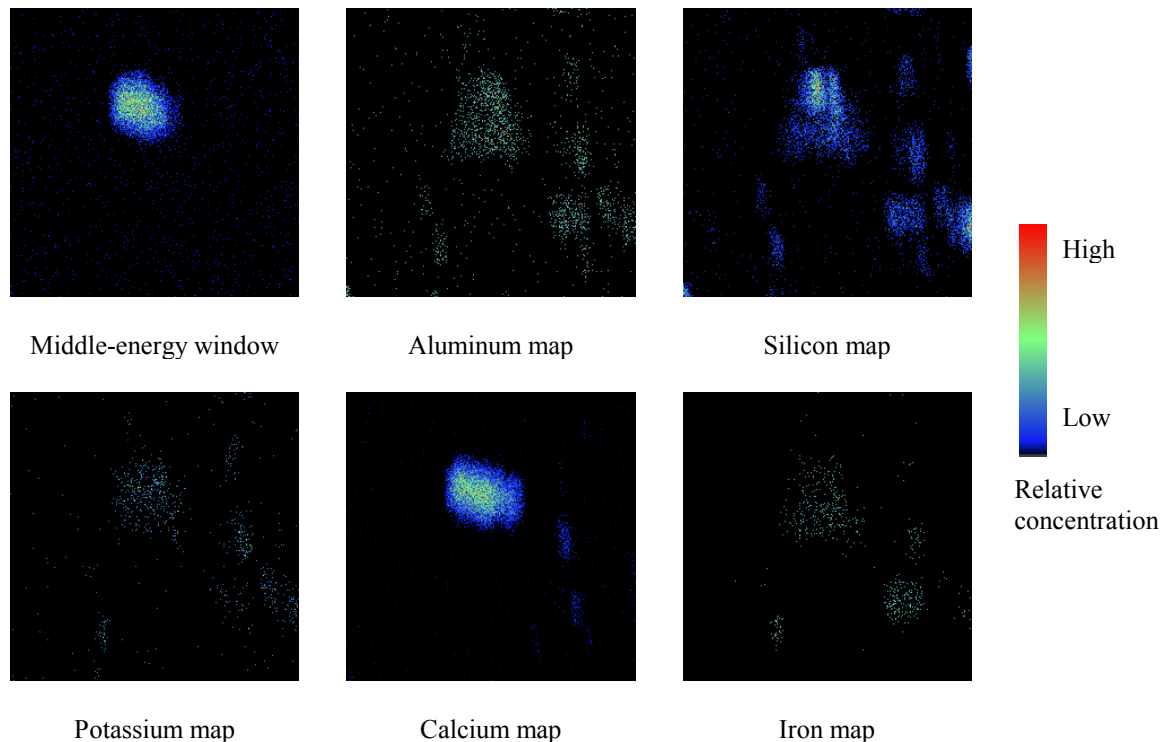

FIGURE 1. STIM image and maps of Al, Si, K, Ca and Fe for a fine sand sample from the Taklimakan Desert. The scanning area of the micro-beam was 100×100 μm.

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