

## **Particle Size/Composition Relationships of Wind-Eroding Sediments, Owens Lake, California, USA**

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**Abstract.** Major (Na, Mg, Al, Si, S, K, Ca, Fe), minor (Cl, Ti, Mn, Sr), and trace (Ni, Cu, Zn, Ga, As, Br, and Rb) element concentrations were determined by PIXE in 118 bulk aeolian dust samples deposited at six heights in seven locations along a 1.2 km long transect during three sequential windstorms at Owens Lake, California, USA. All elements except Ni, Ga, and Br were detected in each sample. Na and S concentrations covaried with each other (and inversely with Si and Ca), increased with height, and decreased with distance downwind and time. Mg, Al, Si, K, Mn, Fe, and Sr concentrations in dust from northerly sites varied with height and location as opposed to nearly constant concentrations at southerly locations. Volumetric particle-size distribution (PSD) for each sample was determined via laser diffraction. PSDs reflected a trimodal distribution: 63% of the samples peaked at 20-50  $\mu\text{m}$  (silt), 11% at 50-100  $\mu\text{m}$  (very fine sand) and 26% at 100-250  $\mu\text{m}$  (fine sand). Most silty samples occurred during the first two events. Significant differences in element concentrations existed in relation to the volumetric percentage of particles in a given size range. Na and S concentrations were proportional to the percent volume of submicron to silt particle fraction during each event. Al, Ti, Mn, K, Fe, and Rb concentrations correlated positively to 100-500 $\mu\text{m}$  (fine/medium sand) particles in the first two events and a wider PSD range 250-1000 $\mu\text{m}$  (coarse sand) in the third event. The results suggest sodium sulfate aerosol emission during the first windstorm, while subsequent saltation-dominated events released more aluminosilicate minerals containing higher trace metal concentrations. These combined techniques reveal particle size/chemical fractioning and small-scale spatial variability of sediments during resuspension at aeolian "hotspots," with implications to geochemical cycling and aerosol source/receptor relationships.

**Keywords:** aerosols, dust, California, sediment, geology.

### **INTRODUCTION**

Generation of aeolian dust particles creates a severe air pollution and health and environmental hazard in the regions downwind of dust sources. Fugitive dust and aeolian sand blowing from the anthropogenically desiccated playa (dried bed) of Owens Lake, California (caused by the diversion of the Owens River) has become a massive environmental problem with extremely high particulate matter concentrations recorded on the playa and in downwind receptor sites (1). This dust aerosol and its source sediments are known to contain elevated concentrations of potentially harmful metallic elements including As, Cu, Cr, Pb, etc. It is also seasonally rich in salts and sulfur (2). In this study, elemental composition and concentrations of aeolian

bulk dust samples collected during the Lake Owens Dust Experiment (LODE) field campaign in spring 1993 were analyzed to determine possible correlations of dust chemistry with particle size, location along the playa surface, height above the playa surface and sequential wind storms.

### **METHODOLOGY**

Aeolian dust samples were collected from three sequential wind storms in March 1993 at Owens (dry) Lake, California. The sampling site was located on the south sand sheet one of the primary dust storm initiation regions of the playa (Fig. 1). The dust samples were collected in Big Spring Number Eight (BSNE) dust samplers (3). The BSNEs were placed at seven locations along a one-kilometer long transect

and oriented from north to south parallel the direction of the prevailing wind (4) (Fig. 2). At each location, individual BSNE collectors were placed with inlets at elevations of 10, 20, 30, 50, 60, and 100 cm above the initial playa surface (4). Figure 2 shows the placement of each BSNE along the selected transect, and also shows an example of the BSNE on the left bottom corner.

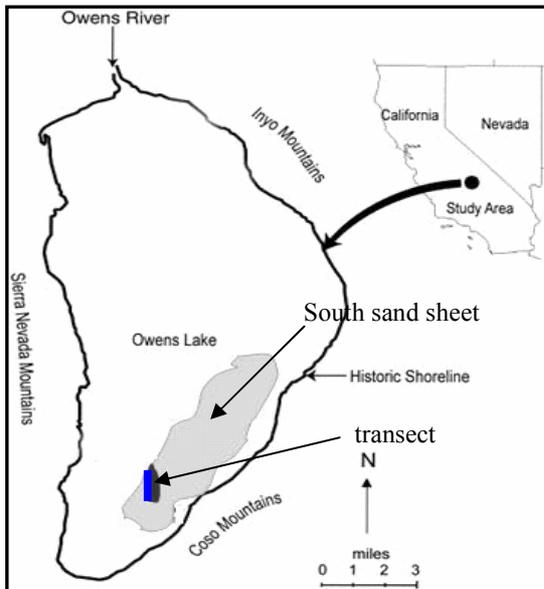


FIGURE 1. Location of study site.

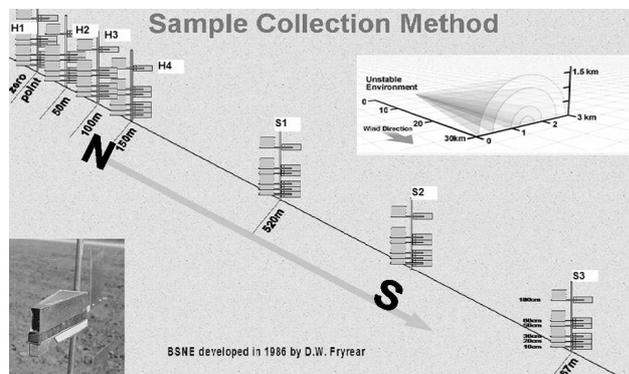


FIGURE 2. Collection method (six heights/seven locations).

Elemental composition/concentrations of aeolian bulk dust samples were determined via Particle Induced X-ray Emission (PIXE) and volumetric particle size distribution (PSD) via laser diffraction. A total of 118 samples, each representing a unique combination of date, location, and height above the land surface, were analyzed. For technical reasons, samples from site S3 were not analyzed.

Dry PSD was determined using a Malvern Mastersizer 2000 laser diffraction particle sizer operating in dry (Sciocco) mode. The protocols recommended by Sperazza *et al.* (5) were generally followed for the particle size analyses.

For elemental analysis, 0.2- 3.0 gram aliquots of dust samples were pulverized in a corundum mortar and pestle to a particle size of 30-50 $\mu$ m or smaller. An aliquot of approximately 0.2 to 1 gram of each powdered sample was pelletized into a 2.5 cm disk between two Kapton films.

PIXE analysis was performed by a General Ionex 4 MV tandem accelerator with a duoplasmatron source capable of producing beam currents in the range of a few nanoamps to tens of microamps, a dual quadrupole focusing lens, an x-y beam scanner to insure beam homogeneity, a beam pulser with 50 ns response time and a vacuum/helium chamber with internal dimensions of 20" w x 16" l x 8" h. The data acquisition system included a computer driving a CAMAC crate front ended with a 150 eV resolution, 30 mm<sup>2</sup> Si(Li) detector for X-ray collection and Au surface barrier detector to monitor scattered protons. Samples were irradiated using a 1.6 cm diameter collimator to enhance overall response for elements and reduce potential for homogeneity issues. Each pellet was irradiated such that it was subjected to a minimum number of proton counts (typically 1 million per sample).

Data reduction was accomplished with a modified version of software developed at the University of Guelph (6). The efficacy of the analyses was verified using USA National Institute of Standards and Technology Standard Reference Material 2711, Montana II Soil, which was pelletized and analyzed under the same conditions during the same run.

## RESULTS

### Variation of Elemental Concentrations With Respect to Sequential Wind Storms

A total of 19 elements were detected by PIXE in the dust samples. They were classified as major (Na, Mg, Al, Si, S, K, Ca, Fe), minor (Cl, Ti, Mn, Sr), and trace (Ni, Cu, Zn, Ga, As, Br, and Rb) elements. All elements except Ni, Ga, and Br were detected in each sample.

Na, Ni, S and Zn concentrations presented a noticeable decrease from the first dust storm (Mar.11) to the second dust storm (Mar.17). A smaller decrease in concentrations was observed from the second storm

to the third (Mar. 23) as depicted for sodium in Fig. 3. The remaining detected elements presented the opposite behavior. In general, their concentrations increased from Mar. 11 to Mar. 17 and continued to

increase more slowly from Mar. 17 to Mar. 23 as shown for aluminum in Fig. 4.

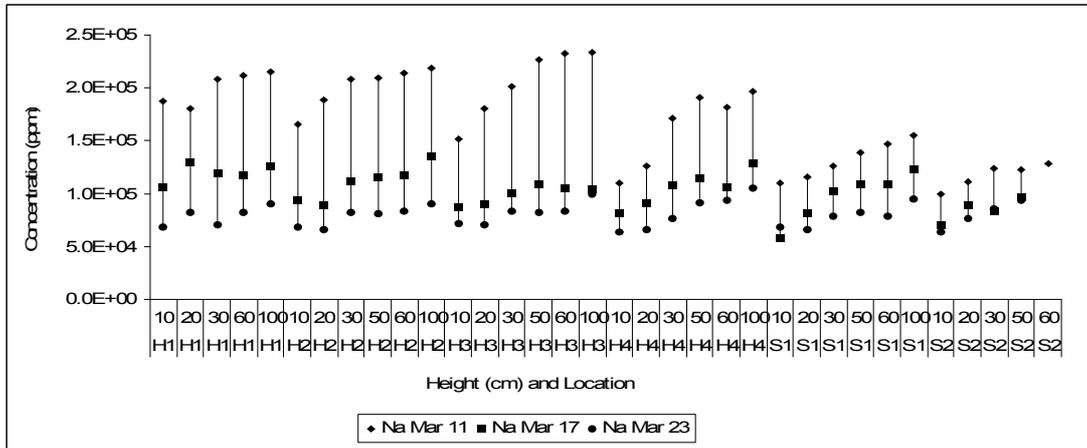


FIGURE 3. Decrease in sodium concentration with sequential dust storms, but increase with height.

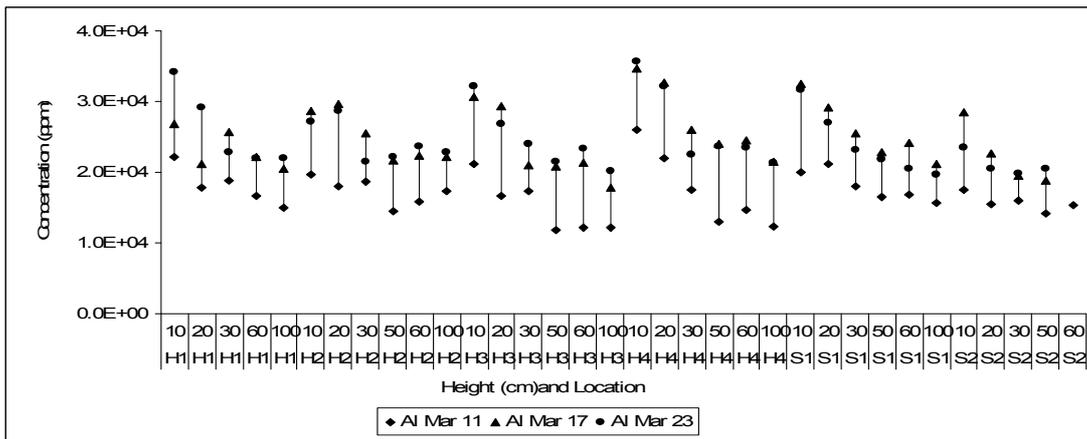


FIGURE 4. Increase in aluminum concentration with sequential dust storms.

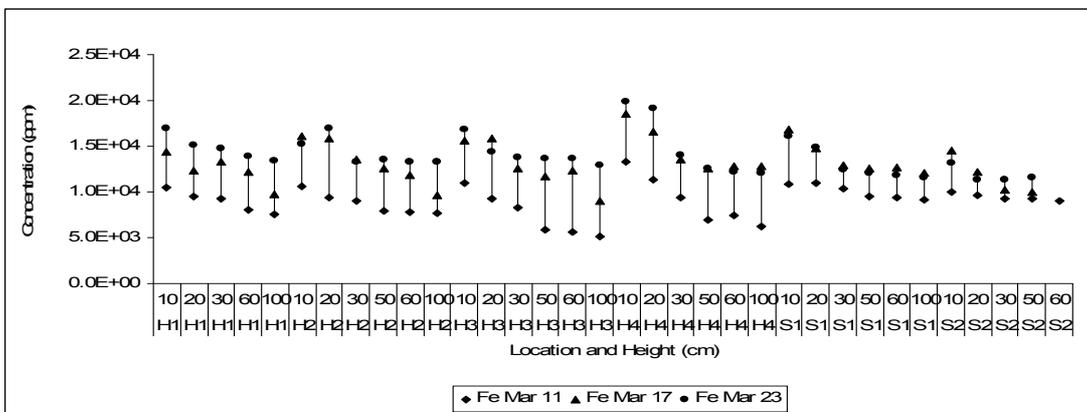


FIGURE 5. Iron concentration variation from northerly sites (H1-H4) compared to southerly sites (S1- S2).

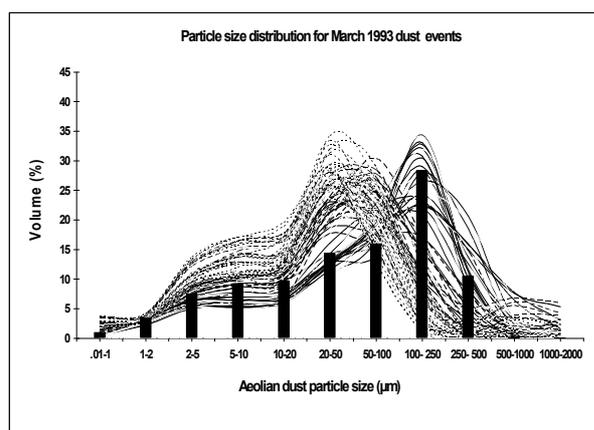
## DISCUSSION

### Variation of Elemental Concentrations With Respect to Height And Location

In general, Na, Ni and S concentrations increased with height and decreased with distance downwind (Fig. 3). Mg, Al, Si, K, Mn, Fe, and Sr concentrations in dust from northerly sites varied with height and location as opposed to relatively constant concentrations at southerly locations (Fig. 4 and Fig. 5). All other elements had no clear pattern when associating variations in concentrations with respect to height or location.

### Variation of Elemental Concentrations Relative to Particle Size

Volumetric PSDs reflected a trimodal distribution: 63% of the samples peaked at 20-50 $\mu\text{m}$  (silt), 11% at 50-100 $\mu\text{m}$  (very fine sand) and 26% at 100- 250 $\mu\text{m}$  (fine sand) as shown in Fig. 6. The majority of samples high in silt content occurred during the first and second dust events.



**FIGURE 6.** Particle size distribution for March 1993 dust events.

Significant differences in element concentrations existed in relation to the volumetric percentage of particles in a given size range. For example, Na and S concentrations varied proportional to the percent volume of submicron to silt particle fraction during each event. Al, Ti, Mn, Fe, K, and Rb concentrations varied positively with the percent volume of particles in the 100-500 $\mu\text{m}$  size range (fine/medium sand) in the first two dust events and with a wider PSD range 250-1000 $\mu\text{m}$  (coarse sand) in the third event. These elements varied, however, inversely proportional to the percent volume of particles in the .01-1 $\mu\text{m}$  and 20-100  $\mu\text{m}$  size range during the three dust events.

The results suggest fine sodium sulfate salt aerosol emissions, primarily during the first windstorm, while subsequent saltation-dominated events released more aluminosilicate minerals containing higher concentrations of most trace metals. These combined techniques reveal particle size/chemical fractioning and small-scale spatial variability of sediments during dust resuspension at aeolian “hotspots,” with implications to geochemical cycling and aerosol source/ receptor relationships. Preliminary analysis of elemental concentration variation in relation to percent volume of particles in a given size range provides the opportunity to explore possible confounding factors such as height and location when correlating aerosol elemental concentrations to particle size distributions.

Future work will investigate the statistical significance of variability and relationships among these factors, and add additional chemical information on the samples obtained via ion chromatography and X-ray diffraction.

## ACKNOWLEDGMENTS

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