

Composition of Mineral Aerosols Generated in the Salt Basin of Far West Texas (USA) using PIXE and Complementary Techniques

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Abstract. The Salt Basin in far west Texas, USA, is a site of active aeolian sand transport and dust emission. Salt Basin playas (dry lake deposits) are a major source of mineral aerosols in arid Southwest North America. These dust storms can be visible from satellite imagery, extend for large distances, and be pervasive for several days. The basin is immediately west of the Guadalupe and Delaware Mountains, which enclose a national park and an Interagency Monitoring of Protected Visual Environments (IMPROVE) aerosol monitoring station. Understanding the chemistry of Salt Basin aerosols and the influences that mineralogy, sedimentology, and hydrological cycles have on dust emissions from the Salt Basin would greatly improve our understanding of aeolian processes at work in this area and aerosol transport to protected ecosystems in the mountains. In this study we monitor seasonal, spatial, and temporal variations in the composition of the aerosols and wind-erodible sediments on the playa surface. Aeolian dust and sand sampling stations were positioned on the Salt Basin playa surface, nearby gypsum dunes, and at the crest of the Delaware Mountains, and have been actively collecting since June of 2005. Elemental analysis of the dust and source sediment samples was performed using Proton Induced X-ray Emission (PIXE), and additional compositional information was obtained through ion chromatography (IC) and X-ray diffraction (XRD). This study elucidates the effects of Salt Basin dunes and playas on regional dust storms and mineral aerosol transport to the adjacent uplands, and the impact of locally-generated dusts on aerosol measurements in the Guadalupe Mountains.

Keywords: aerosols, dust, geology, sediments, North America.

INTRODUCTION

The Salt Basin [1] lies mostly in Texas (Hudspeth and Culberson Counties), with a small part of the basin extending into Otero County, New Mexico, USA. A remote sensing image of the Salt Basin is shown in Figure 1. Its width ranges from 8 to 32 km, and the length is about 225 km. The Salt Basin is a closed basin, that is, no surface drainage leaves it. Recharge to the Salt Basin fill is mainly by runoff from the bordering mountains into alluvial fans. Its floor is characterized by numerous dry lakes (playas) and ponds, gypsum dunes, and extensive halite deposits. The deposits in the Salt Basin consist of clay, sand, gravel, caliche, and, in places, volcanic rocks and volcanoclastic deposits, and include minerals such as calcite, aragonite, dolomite, and minor amounts of magnesite, celestite, and native sulfur. Dunes in the Salt Basin cover about 800 ha and are composed of largely granular gypsum blown in from the salt flats. Winds blowing across the various Salt Basin sediments raise dust clouds which are transported long distances downwind. Using MODIS satellite imagery several dust source locations were identified within

and around the basin to monitor and sample the mineral aerosols being emitted in the area.

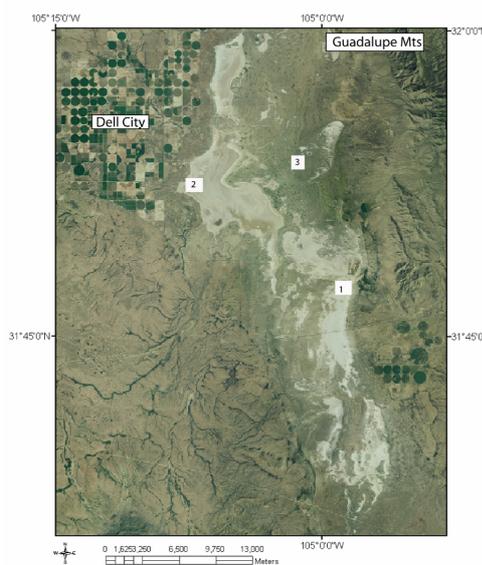


FIGURE 1. Location of Salt Basin showing sampling sites. Site 4 is to the SE at the crest of the Delaware Mountains. Region located at approx. 32°N latitude by 105°W longitude.

MATERIALS AND METHODS

Sixty-four samples of playa surface evaporites were collected on September 25 and September 30, 2005. Field data acquisition included an approximate 5-10 g of surface sample material, brief description of the surface features, spectral signature, and a photograph of each site. Six transects were completed with a sampling interval of 100 m. Transects were offset by 50 m to obtain better data dispersal. Each transect contained between 9 and 12 sampling sites depending on variable extent of the playa surface.

Four passive dust sampling sites (Figure 1) were established during June and July 2005. Two were positioned in proximity to dust sources identified from satellite imagery: Site 1 at the edge of a large playa and the Site 2 towards the center of the playa. A third site was established in the gypsum dune area in the northern part of the basin, and a fourth site was set up at the IMPROVE aerosol monitoring station on the crest of the Delaware Mountains overlooking the southeastern part of the basin. At each site BSNE samplers [2] and marble dust traps [3] were deployed. Accumulated sediment was collected from them using the procedures recommended in references [2] and [3] approximately seasonally until the present (Table 1).

TABLE 1. Sampling dates, locations at different heights (shown on Figure 1).

SITE	OCT 23-05	JAN 24-06	MAY 08-06	DEC 16-06
PLAYA1A	■		■	■
PLAYA1B	■		■	■
PLAYA1C	■		■	■
PLAYA2A	■		■	■
PLAYA2B	■		■	■
PLAYA2C	■		■	■
DUNES3T		■	■	
DUNES3C		■	■	
IMPROVE4D				■
IMPROVE4C		■	■	■

Analytical Procedures

The samples collected from the BSNEs, marble dust traps and surface sediments were analyzed using various methods to evaluate particle size distribution and elemental, ionic, and mineral composition.

Particle size distribution

Each sample was analyzed for particle size distribution using a Malvern Mastersizer 2000 laser diffraction particle sizer. The samples were first sieved using a 1.44 mm opening manual sieve to remove large particles. Dry particle size analysis was performed on 10-20 g of material for surface samples and 1-10 g of BSNE and marble trap captured dust. Wet particle size analysis was performed on 5 g of material mixed with 20 mL of 5% sodium hexametaphosphate (Calgon) solution which was then shaken for 8 hrs before testing. The protocols of Zobeck [4] and Sperazza *et al.* [5] were generally followed for the particle size analyses.

Proton Induced X-ray Emission (PIXE)

Dust and surface sediment samples were pulverized in a corundum mortar and pestle. Approximately 3-5 g of surface sediment was powdered, while a lesser amount of BSNE and marble dust trap samples was available, depending on sampling locality and date. An aliquot of approximately 0.2 to 1 g 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 na to tens of μ a, a dual quadrapole 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 50 cm w x 40 cm l x 20 cm h. The data acquisition system included a computer driving a CAMAC crate front ended with a 150 eV resolution, 30 mm² 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 accuracy 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. The elemental concentrations were within the levels certified for the SRM except for S, which presented too high of a concentration with PIXE: thus, caution is advised in interpreting sulfur values in these data.

Ion Chromatography (IC)

Each sample was analyzed for ionic compositions using a DIONEX 500 ion chromatograph. One gram of the sample was diluted in 14 mL of distilled ultrapure water and was centrifuged for 30 min. The concentrate was then filtered through ashless filter paper in order to ensure that the sample did not contain any solid material. In order to constrain the conductivity to around 1000 μ S, some samples required further dilution with distilled water. This dilute was then tested.

X-Ray Diffraction (XRD)

An approximate 2-3 g of the samples was used for mineralogical analysis via X-ray diffraction. The samples were first manually ground to a fine powder using a corundum mortar and pestle. This powder was then prepared onto a 27 mm by 46 mm petrographic slide using petroleum jelly as the gluing agent. A very thin film of the jelly was first smeared onto the slide which was then sprinkled with the sample powder. Excess powder was removed in order to analyze a thin layer of the sample. The powder was then analyzed using an XDS 200 instrument.

PRELIMINARY RESULTS

A total of 27 dust samples and 63 surface samples have been obtained to date. Particle size distribution analysis shows grain size values of 100-1000 μ m predominate in the surface samples, while particle size in dust samples fluctuates between 50-150 μ m in samples collected in the early summer months (winter acquisition) and 100- 1000 μ m for samples collected in the fall (summer acquisition). There is a change in the particle size, fining upward, with samples collected at higher BSNE and marble dust trap heights.

Ion Chromatography analysis has been performed on 20 dust samples and 31 surface samples to date. Data has shown the presence of Na, Mg and Ca as the major cations. The major anions present were Cl, NO₃, and trace amounts of F.

PIXE results show that the playa surface composition is fairly homogeneous. There was very little variation for the test area in the northern part of the salt pan as is shown in Figure 2. The results were consistent with the known mineralogical composition; Ca and S for example correspond to gypsum (CaSO₄·2H₂O), Na and Cl are related to the mineral halite (NaCl), and Mg can be associated with dolomite (CaMg(CO₃)₂). The results were also consistent with the various analytical techniques utilized.

Dust composition varied with dust trap height off the ground, as shown in Figure 3 for samples collected during summer 2005. Higher concentrations of Mg and Ca were found in samples collected at .5 m height while Si, Cl and Fe had highest concentrations in traps elevated 1.2 m or higher. For most elements height differences between the two BSNE samplers at .5 m (A) and 1 m (B) did not affect concentrations.

Although there is only a relatively small variation in chemical composition of playa surface, there is greater variation in the composition of dust samples acquired during different seasons and locations. As an example, Figures 4a and 4b show elemental composition of dustfall during the 2005-2006 winter/spring (windy) season (samples collected on May 8, 2006). Dust at the two salt playa sites has generally similar concentrations of many elements, but sites 3 (gypsum dunes) and 4 (IMPROVE site) show increased amounts of Si and decreased Cl. Samples collected within the playa surface (site 2) and the gypsum dunes (site 3) site show very similar concentrations of K and Fe. Concentrations of these elements are much different at the dust trap at the playa edge (site 1) and at the IMPROVE site (site 4). The playa edge site shows a lower concentration of these elements while the IMPROVE site shows a tri-fold increase in the concentrations of K and Fe.

Many elements do not demonstrate such a change in composition with location, although there are some variations for elements such as Si and Ca. In general, the dust collected at the mountaintop IMPROVE site appears compositionally different from the dust at the three collection locations on the basin floor.

CONCLUSIONS

Several observations can be made with the preliminary data. Dust composition will be affected by parameters including location of emission, wind speed and direction, topography of the area traversed by the aerosols, and the size of particles entrained by the wind. Temporal variations of precipitation and groundwater influx will alter the chemistry and size of surface particles available for deflation. For example, during very wet years there will be more saline soils on the playa surface, which may be more easily eroded than heavier clastic soils. Variations in the mineralogy of the soils will inhibit or increase mobility of certain elements within the Salt Basin floor, causing spatial changes in the chemistry of the playa.

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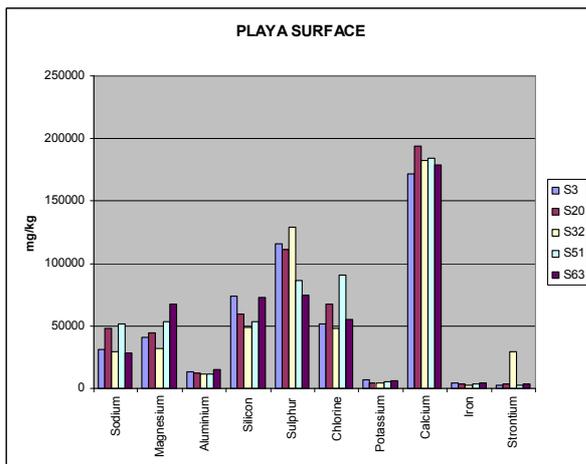


FIGURE 2. Playa surface composition at various points.

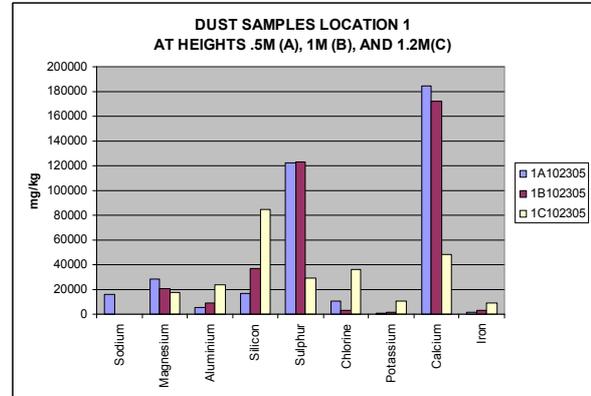


FIGURE 3. Dust composition at Site 1, October 2005, at three heights off the ground.

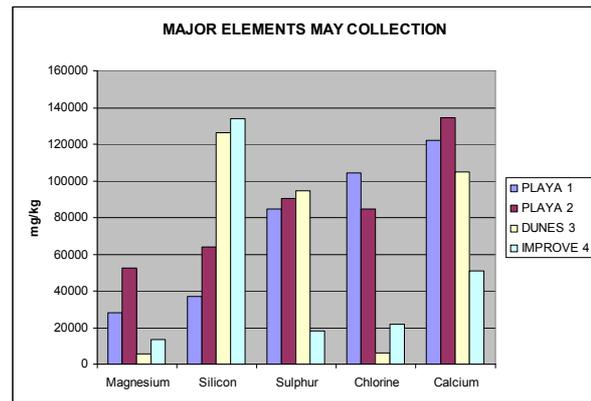


FIGURE 4a. Major element composition, sites 1-4.

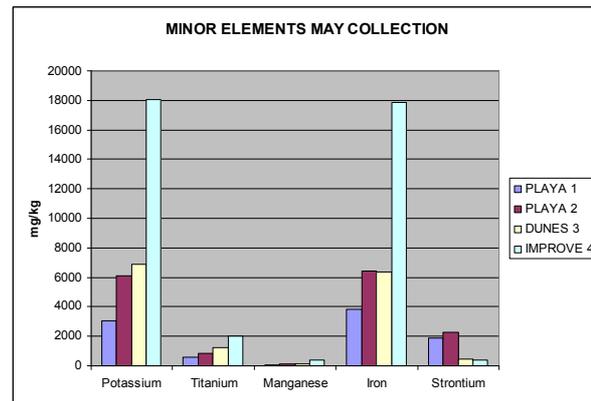


FIGURE 4b. Minor element composition, sites 1-4.