Aeolian Additions: The Downwind Effects on Soil and Vegetation in Owens Valley

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Project Objectives

The objective of this study was to determine the impact of Owens Lake Playa dust on the nearby soils of Owens Valley. The playa has been a significant dust source for about 100 years and during this time it has been one of the largest point sources of PM-10 dust in the United States (Gill and Gillette, 1991). Dust composition and deposition rates on the lakebed and downwind of the lakebed have been measured since 1991 by the USGS, to provide data on the amount and composition of dust likely to be incorporated into the soils (Reheis, 1997). We hypothesized that the alluvial piedmont soils surrounding Owens Valley, and in particular, those within 30 or 40 km of Owens Lake playa are acting as a long-term dust trap. We expect that playa dust, high in clay and silt sized particles and sodium, sulfate, and carbonate-rich salts will be reflected in nearby soils through an increase in silt and clay sized particles, higher electrical conductivity (a measure of salt content), pH and sodium adsorption ratio. Hence, this research documents the impact of introduced dust components on soil chemistry, particularly salinity, sodicity, and texture. We also document the spatial impact of the dust by considering distance from the playa and the contrast between the chemistry and mineralogy of the playa derived dust and the background, regional dust rain that has impacted the soils at least during the Holocene. Our results demonstrate the extent to which the prodigious dust clouds impact the ecosystems of Owens Valley. An evaluation of the extent of that impact is a critical step toward assessing management decisions related to Owens Lake Playa as well as other similar dust sources, such as the Salton Sea, that may become desiccated in the future.

PROJECT OBJECTIVES ADDRESSED

We sampled soils along a transect running from north-northwest to south-southeast along the valley axis to compare accumulation of salts and fine-grained minerals both with respect to dust trap samples collected near our sampling sites and with respect to distance from the playa source for the dust. Sites were selected on alluvial fan deposits emanating from the Sierra Nevada batholith granites. Fieldwork included the training of graduate student, Dayna Quick, in appropriate site selection, soil pit excavation and site description. We obtained samples of designated soil horizons from each of the research pits in the field, along with horizon descriptions of depth, boundary, color, rock fragments and structure.

In the laboratory, we developed horizon-by-horizon inventories of silt + clay, electrical conductivity (EC), water extractable salts, sodium adsorption ratio and pH on the same-age, same-mineralogy parent material afforded by post-glacial granitic alluvium. Contrasts between

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the $^{87}\text{Sr}/^{86}\text{Sr}$ of the playa dust and the soil weathering endmembers allow us to develop quantitative estimates of not only the role of salts and fines in the soil profiles but also to assign fractions of contribution from the different sources. To determine the long-term dust signature, we also collected samples, both north and south of the playa, from volcanic outcrops that serve as natural, long-term accumulators of airborne dust, and only dust, in the valley.

**Approach and Procedures**

**Fieldwork**

To identify the potential point-source impact of Owens Lake Playa dust on valley soils, we compared soils of relatively the same age and parent material--formed in the end-of-glacial alluvial piedmont on the Sierra Nevada side of the valley. Several fan surfaces in Owens Valley have been dated; however the number of sites necessary for our study required us to employ additional ways of ensuring that we sampled comparable soils in different geographic locations. If in the process of soil excavation we have encountered a strong Bt or argillic horizon, we have assumed it to be a relict soil from earlier glacial times. Because we cannot be absolutely certain in regard to the age of fan and soil, we’ve redefined our parent material goal as being constrained to soils with similar particle size distribution, and therefore similar water holding capacities and other soil properties that would create similar responses to aeolian input. Soils sampled are loamy sands and sandy loams, with clay ranging from 2 to 10% and silt from 7 to 35%.

We chose to sample one soil that was close to the playa and was recognized as a dust-impacted soil to provide us with a clear template for the signals that we would be looking for in the more broadly distributed sites. Based on work done by Bierman, et al 1995, we have a degree of certainty about the age of this site; the Alabama site (H on map in

![Figure 1 Map of Owens Valley with sampling sites](image)

(A: Fish; B: Taboose; C: Thibaut; D: Briar; E: HOG (3,4); F: HOG (1,2); G: North Alabama (NORAL); H: Alabama; I: Cottonwood; J: Ash; K: Sage; L: Tunawee; M: Coso)
Figure 1). This site will be analyzed and discussed in detail in the RESULTS AND DISCUSSION section of this paper.

**Laboratory**

For electrical conductivity, we used a 1:1 soil extract based on the method provided in Rhoades, 1982. This extract was also used for elemental analyses of the water-extractable salts (Ca, K, Mg, Na, As, Ba, Li, Sr) using ICP-AES. Soil reaction was measured using 1:1 water electrometric method based on that provided in Hendershot et al 2008 and Soil Survey Staff 2004. Particle size distribution was determined using adapted methods of the Pipette method as outlined in Day, 1965; Janitzky, 1986; Gee and Bauder, 1986; Sheldrick, 1993 and Soil Survey Staff, 2004. Soil samples were pretreated to remove soluble salts and carbonates (using NaOAc) and organic matter (H₂O₂).

To characterize the Sr isotopic composition of the soluble component of soil horizons, we used a filtered 1:1 soil-water extract, isolated and concentrated the Sr using ion exchange resins, (see Capo et al., 1998) and measured the Sr using a Thermalization Mass Spectrometer. Originally, the soil weathering endmember 

\[ { }^{87}\text{Sr}/ { }^{86}\text{Sr} \] values were thought to lie between 0.706 to 0.708, which is the estimated value of most of the surrounding Sierra Nevada granitoid bedrock and alluvium (Kistler and Peterman, 1973). This would provide a difference between playa dust values (\( { }^{87}\text{Sr}/ { }^{86}\text{Sr} \) is 0.7091 to 0.7092, Pretti and Stewart, 2002) and parent material values great enough to allow us to quantify mixing of ions from the two endmembers in soil solutions. However, preliminary data from our soil solutions showed a range of \( { }^{87}\text{Sr}/ { }^{86}\text{Sr} \) ratios, with some being higher, or more radiogenic, than the values for the playa dust. We therefore leached the C-horizons of our soils consecutively with water, acetic acid, and finally nitric acid and measured the ions in the final nitric acid leach to determine the likely endmember contribution from weathering of alluvium at each site.

**Results and Discussion**

Presented here are results from the thirteen soil-sampling sites, labeled A-M on Figure 1. Select data results are organized in graphs presented in Figures 3-7 found in Appendix A at the end of this document. One of the soil-sites, Cottonwood (I), is not included in further analyses or the discussion because it was too sandy to meet our particle-size criterion as described above. Additionally, another of the sampling sites, Alabama (H) will be analyzed separately and in detail due to indications of an elevated dust component to the soil. After looking at this soil in detail, the other soils’ properties will be looked at with respect to depth in the profile and distance along the valley axis.

**ALABAMA**

The Alabama soils are located on an 8-12 ky age-dated alluvial fan surface just east of the Alabama Hills and west of the city of Lone Pine. This site is located 55 km south-southeast on the axis from the northern most sampling site, and just 8 km from the northern end of the playa. The morphological properties of these soils, particularly accumulation of an Av horizon made it clear that they had been subjected to greater dust accumulation than other post-glacial soils we observed in Owens Valley. We selected this soil as a test case to evaluate the maximal effect of
playa contributions to the predominately coarse grained soils on the granitic alluvium on the west side of the valley. We reiterate that there is no evidence that Owens Lake dried out prior to the 20th century.

**Soil Properties**

The two Alabama soils are gravelly sandy loams, with clay ranging from 3% to 10%, and silt ranging from 14% to 35%. Both soils 1 and 2 at the site have a vesicular horizon occurring at 0-5 cm and 3-10 cm, respectively. These vesicular horizons contain twice as much or greater clay and silt as in the lower horizons. The average pH of the Alabama soils is 10.0, the highest of all the soils sampled. pH remains fairly consistent with depth, the exception being the top horizon of soil 2, which measures 9.1. Electrical Conductivity (EC) here is exceptionally high, compared to all other soils sampled, and the horizons range from about 250 µ/cm to more than 1100 µ/cm. This is the only measurement that shows an appreciable difference between two soil pits at any given site. Both soils show a continuing increase in salts below 20 and 30 cm depth. The Sodium Adsorption Ratio (SAR) ranges from 12.5 to 21.3, and is elevated in the mid to lower parts of the profile. These values, along with a pH greater than 8.5, indicate that these are sodium affected soils.

![Graphs of clay and silt, pH, SAR and EC at Alabama (Pit 1 values in black, Pit 2 values in gray)](image)

**Strontium (Sr)**

The $^{87}\text{Sr}/^{86}\text{Sr}$ values of the water leaches for horizons 1 and 5 are 0.70910 and 0.70930, respectively, and the $^{87}\text{Sr}/^{86}\text{Sr}$ value of the nitric acid leach for horizon 6 measures 0.70958. Knowing the playa dust has an average $^{87}\text{Sr}/^{86}\text{Sr}$ value of 0.7091 (Kathleen Simmons and Marith Reheis, USGS, unpublished data), we were able to use the simple mixing equation below to determine the relative contributions of aeolian input (playa dust) and soil mineral weathering to the soluble salts in horizons 1 and 5 of Alabama 2.
Equation 1: Simplified mixing equation

\[
\frac{M_1^{Sr}}{M_1^{Sr} + M_2^{Sr}} = \frac{(^{87}Sr/^{86}Sr)_1}{(^{87}Sr/^{86}Sr)_2} - \frac{(^{87}Sr/^{86}Sr)_2}{(^{87}Sr/^{86}Sr)_2}.
\]

According to the above equation, the soluble salts measured in soil horizon 1 show a 100% contribution from playa dust, whereas salts in horizon 5 show a 60% contribution from playa dust and a 40% contribution from weathering minerals within the soil itself. This is a clear indication that dust from Owens Lake Playa is being incorporated into nearby soils. Though results indicate that playa dust contributes only 60% of the soluble salts in horizon 5, the EC and SAR are elevated as compared to horizon 1. This may be an indication that sodium is selectively or preferentially leached lower into the profile, while ions such as Ca, Mg and Sr remain concentrated in the upper horizons.

**OTHER SOILS LOCATED ALONG THE VALLEY AXIS**

**Soil Properties with Depth**
(Referenced graphs are in Figures 3-6 in Appendix A at the end of this document)

**Particle Size Distribution**
Soils sampled for this comparative study have loamy sand and sandy loam textures. Many sites (Briar, Hog (1,2) and (3,4), North Alabama, Alabama, and Coso) see an increase in silt within 5-25 cm depth, but then a subsequent decrease with depth. The average silt for the soils sampled in the broader vicinity is 15%, and range from about 7% to 25%. Only four soil samples have silt values outside two standard deviations from the mean, and they occur within the second horizons, or within the upper 15 cm of the soils at Alabama, and North Alabama (NORAL) sites. These sites are located just north and west of Owens Lake playa. The average clay % of all soil samples is about 4%, and range from 1.4 % (in the upper horizon of Ash 1) to 9.6% (in a lower horizon of HOG 3). For all the soils there is little to no increase in clay with depth, which can be typical of young soils in arid and semi-arid regions with little profile development (refer to Figure 3).

**pH**
The pH of these soils range from 6.8 to 8.7. All soils have a lower pH in their upper horizon, and then show an increase in pH within the upper 10 or 15 cm of their profile, reflecting the same pattern as the Alabama soils. The pH stays relatively constant within the lower horizons of the soil profiles. The slightly lower pH of the upper horizons is likely influenced by the addition of organic matter at the surface (refer to Figure 4).

**Electrical Conductivity (EC)**
Values range from as low as 15\(\mu\)cm to 337\(\mu\)cm. Where the EC of the surface gravel layer (depth of less than 1 cm from the surface) has been measured separately, the values of those...
surface layers are 1.5 to 6 times as high as the values measured in the top horizons minus the surface gravel layer. Continuing in depth, salts in the soil profile decrease significantly and remain low, sometimes increasing again in the lowest horizon(s). The exceptions to this are Alabama, North Alabama, and one of the pits at the Sage site. These exceptions show an increase in salts around 20 to 25 cm below the surface, and in the case of the Alabama soils, continue to increase with depth (refer to Figure 5).

**Sodium Adsorption Ratio (SAR)**

The SAR of the soils sampled increase with depth in the profile, often doubling, but remain low in all profiles sampled. The values range between 0.1 and 2.2, with the lowest values found in the upper horizons (minus the surface gravel layer) (refer to Figure 6).

**Soil Properties with Distance**

(Refer to graphs in Figure 7 in Appendix A at the end of this document)

Depth-weighted averages were calculated at depths of 5-10 cm, 10-40 cm, and 40+ cm. Figure 7 shows these averages plotted with distance along the NNW-SSE valley axis. These plots show a jump in values of pH, EC and SAR beginning just north of Owens Lake playa, at North Alabama (G) and Alabama (H, not shown on these graphs), and remain elevated adjacent to and south of the playa at Ash, Sage and Tunawee (J, K, and L) before decreasing again at Coso (M). These elevated values cover a distance of more than 65 km, extending 15 km north of the playa and 26 km south of the playa. EC and SAR are especially elevated in the soil profiles below 40 cm depth, showing that the Na component of soluble salts tends to move and accumulate further down in the soil profile than Ca and Mg.

**Strontium (Sr)**

$^{87}\text{Sr}/^{86}\text{Sr}$ ratios for the soil solutions range from a less radiogenic 0.70876 to a more radiogenic 0.71031. Over half of the soil solutions had $^{87}\text{Sr}/^{86}\text{Sr}$ ratios more radiogenic than the assumed weathering endmember values (0.706 to 0.708) and measured playa dust values (0.7091), calling into question the assumed soil weathering endmember value. Thus we started measuring the Sr isotopic contribution from each site’s parent material by performing nitric acid leaches on their respective C horizons. The six C horizons we have analyzed thus far have $^{87}\text{Sr}/^{86}\text{Sr}$ values that vary from 0.70855 to 0.70996. We use four of these six measurements in the simple mixing equation (Equation 1 in this paper) to present relative contributions to soils at the HOG, Alabama, Ash and Coso sites. (See Table 1, below).
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<table>
<thead>
<tr>
<th>Soil Site</th>
<th>Horizon</th>
<th>$\text{Sr}^{87}/\text{Sr}^{86}_{\text{mix}}$</th>
<th>$\text{Sr}^{87}/\text{Sr}^{86}_{1}$</th>
<th>$\text{Sr}^{87}/\text{Sr}^{86}_{2}$</th>
<th>$M_1$ (% dust)</th>
<th>$M_2$ (% soil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOG (1,2)</td>
<td>1</td>
<td>0.70903</td>
<td>0.7091</td>
<td>0.70855</td>
<td>87</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>0.70911</td>
<td>0.7091</td>
<td>0.70855</td>
<td>102</td>
<td>-2</td>
</tr>
<tr>
<td>ALABAMA</td>
<td>1</td>
<td>0.70910</td>
<td>0.7091</td>
<td>0.70958</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>0.70930</td>
<td>0.7091</td>
<td>0.70958</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>ASH</td>
<td>1</td>
<td>0.70907</td>
<td>0.7091</td>
<td>0.70866</td>
<td>93</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>0.70905</td>
<td>0.7091</td>
<td>0.70866</td>
<td>89</td>
<td>11</td>
</tr>
<tr>
<td>COSO</td>
<td>1</td>
<td>0.70937</td>
<td>0.7091</td>
<td>0.70996</td>
<td>69</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.70971</td>
<td>0.7091</td>
<td>0.70996</td>
<td>29</td>
<td>71</td>
</tr>
</tbody>
</table>

Table 1 Four soil sites and corresponding soil solution and weathering endmember strontium values used in Equation 1 to calculate relative contribution of playa dust and soil mineral weathering to soluble salts in the profiles

$1= \text{playa dust endmember}; \ 2= \text{soil mineral weathering endmember}; \ \text{mix}= \text{soluble salts of the soil profile}$

$M_1^{\text{Sr}} = \text{Mass or percent playa dust contribution}; \ M_2^{\text{Sr}} = \text{Mass or percent soil mineral weathering contribution}$

Three of the four soils show a greater playa dust contribution in their upper horizons with the exception of Hog, which shows greater playa dust contribution in the lower horizon. Those soils just north and adjacent to the playa (Alabama and Ash) exhibit higher contributions than Coso to the south and Hog further north.

Summary

Silt, clay and salts blown as dust from Owens Valley playa have impacted the soils surrounding the playa, both spatially and with depth. We measured the relative contribution of playa dust to the surrounding soils using standard soil measurements and using strontium isotopes. We have thus far quantified playa dust inputs to soils in four locations near the playa and determined, in depth, the input and impact of one nearby soil in the Alabama Hills. We used this profile as an example of the possible effect on other surrounding soils over the next 100 years if the playa dust is not significantly mitigated. The Alabama soils have high measures of electrical conductivity (used as an indirect measurement for salts), an average pH of 10.0 and a sodium adsorption ratio greater than 15, classifying them as sodic soils. Other surrounding soils show a likely playa dust input that appears greatest just north of and adjacent to the playa and decreases with distance from the playa. Though pH, EC and SAR are within normal soil ranges, this is likely due to the fact that they are younger, sandy soils that tend not to retain salts in their profiles. With these normal measures we would not expect an impact on vegetation, however we would expect to see a greater impact on older, more developed and siltier soils that hold more salts, as well as soils on the valley floor and possibly the eastern side of valley. We will continue to analyze the spatial impact of playa dust as more $\text{Sr}^{87}/\text{Sr}^{86}$ data are processed.

Well into our research we made an important discovery that has wider implications for the larger research community. Though we originally planned to use a previously documented Sierra Nevada granitic alluvium $\text{Sr}^{87}/\text{Sr}^{86}$ weathering endmember, early $\text{Sr}^{87}/\text{Sr}^{86}$ measurements...
indicated that we needed to measure our weathering endmembers on a site-by-site basis. Our granitic alluvium weathering endmembers have been found to range from as low as 0.70855 to as high as 0.70996. These $^{87}\text{Sr}/^{86}\text{Sr}$ values are higher than the previously assumed 0.706 to 0.708 range. This discovery of the need to sample on a site-by-site basis provides an important example to others performing similar soil-ecosystem mixing calculations involving generic $^{87}\text{Sr}/^{86}\text{Sr}$ values.

We will likely rework our plan for vegetation analyses from what was originally proposed, due to normal soil properties in our sandy soils, by performing a vegetation surveillance at the Alabama site and at one or more sites having similar but less salt and sodium effected soil. We would also like to collect plants at different sites to conduct leaf ion analyses to determine if they are reflecting a similar dust component ratio to those found in the underlying soils.

After compiling all of our $^{87}\text{Sr}/^{86}\text{Sr}$ data, we will attempt to use these measurements to predict the impact over the next 100 years assuming a constant rate based on dust deposition data collected by the USGS and applied to the last 100 years. We will then endeavor to answer the question of how long it would take before we would see an impact on the surrounding soils that would effect plant species composition and health.

References


Aeolian Additions: The Downwind Effects on Soil and Vegetation in Owens Valley—Chadwick


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APPENDIX A

(additional figures referenced in paper)
Aeolian Additions: The Downwind Effects on Soil and Vegetation in Owens Valley—Chadwick

Figure 3: Graphs showing % clay and silt with depth for all soils at each sampling site

- PERCENT CLAY AND SILT
- DEPTH IN PROFILE
- 1 CLAY
- 1 SILT
- 2 CLAY
- 2 SILT

- PERCENT
- DEPTH IN PROFILE
- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80

- FISH (A)
- TABOOS (B)
- THIBAUT (C)
- BRIAR (D)
- HOS (3,4) (F)
- HOS (1,2) (F)
- NORAL (G)

- ALABAMA (H)
- COTTONWOOD (I)
- ASH (J)
- SAGE (K)
- TUNA (L)
- COSO (M)
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Figure 4: pH with depth

- pH vs. Depth in Profile
  - FISH
  - TABOUSE
  - THIBAUT
  - BRIAR
  - HOG (3,4)
  - HOG (1,2)
  - NORAL
  - ASH
  - SAGE
  - TUNA
  - COSO
Aeolian Additions: The Downwind Effects on Soil and Vegetation in Owens Valley—Chadwick

Figure 8 Sodium Adsorption Ratio (SAR) with depth

- FISH
- TABBOOSE
- THIBAUT
- BRIAR
- HOG (3,4)
- HOG (1,2)

- NORAL
- ASH
- SAGE
- TUNA
- COSO
Figure 7 Soil Properties with distance NNW-SSE (shaded area signifies the location of Owens Lake Playa along the sampling axis)

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