FURTHER DISCUSSION OF DUST DEPOSITION AND FIELD-BASED MEASUREMENTS

Surficial-Geologic Mapping and Surface Descriptions

The surficial geology of Eagle Mtn. piedmont (Fig. 1B) was mapped and correlated to the regional chronosequence of Whitney et al. (2004) using elevation above active channels, terrace dip, depth-of-dissection, degree-of-planarity, and the development of pavement, varnish, and calcic soils as relative-age indicators (McFadden et al., 1987; Bull, 1991). Holocene and Pleistocene units were readily distinguished using pavement and varnish development, as is the case elsewhere in Amargosa Valley (Whitney et al., 2004). Degree of surface planarity was particularly useful for distinguishing between middle-to-late (Qa2) and late Pleistocene (Qa3) units, both of which have moderate to strong pavement and varnish development. Middle-to-late Pleistocene terraces are “crowned,” reflecting a longer interval of diffusive hillslope adjustment compared to late Pleistocene surfaces. Photographs of type-example terrace units are given in Figure DR1. Approximate ages have been assigned based on the regional chronology of Whitney et al. (2004). These authors (and references therein) established a uniquely detailed Quaternary alluvial chronology in northern Amargosa Valley and surrounding areas in support of the Yucca Mountain Project. Terraces on the Eagle Mtn. Piedmont range in age from middle Pleistocene (Qa2), middle to late Pleistocene (Qa3), late Pleistocene (Qa4), and latest Pleistocene to recent (Qa5-Qa7) based on this correlation. It should be noted that the absolute age of each terrace unit is not critical to our study. Mapping was necessary to correlate units so that deposit thickness could be compared on surfaces of comparable age. Constraining the absolute rates of deposition was not attempted.

We utilized surface characteristics uncontrolled or only loosely controlled by dust influx to the greatest extent possible in our mapping. In particular, we relied heavily on the degree-of-planarity and the degree of preserved bar-and-swale microtopography in order to distinguish between surfaces and correlate with the Whitney et al. chronology. As one walks up from the active channel, older surfaces are characterized by a systematic decrease in bar-and-swale texture and a gradual rounding of gully and terrace edges by diffusive hillslope processes. Hsu and Pelletier (2004) documented the usefulness of gully-profile information in relative surface-age dating. Desert varnish and clast rubification can be used to differentiate between Pleistocene and Holocene surfaces, and therefore provides an approximate absolute-age “calibration” for the two other relative-dating methods. We discuss each of these relative-dating methods in detail below.

On both Eagle Mountain piedmont and the type-example surfaces of Whitney et al. (2004) (i.e. Yucca Flat/Fortymile Wash fan), hillslope erosion has performed only minor rounding of Qa6 and Qa5 surfaces. Terrace-bounding scarps of these surfaces rise abruptly to planar surfaces over a distance of less than 1 meter. On Qa4 surfaces, the terrace-bounding scarp is wider: backwearing and hillslope rounding has penetrated 2-4 meters horizontally into the terrace tread. The extent of hillslope rounding increases greatly as one steps up onto the Qa3 and Qa2 deposits (to approximately 10 m and 20-40 m, respectively), reflecting the much longer duration of hillslope erosion experienced by those surfaces. Utilizing the extent of preserved bar-and-swale texture and microtopography is potentially problematic as a correlation tool because this process is partly dependent on eolian influx. However, bar-and-swale evolution it is also strongly driven by creep (freeze-thaw cycles) and bioturbation.

Two-Dimensional Model Approximations

Two-dimensional (2D) model solutions identify a fundamental length scale for downwind deposition. Smith (2003) showed that (3) can be approximated a power-law function along the plume centerline:

$$c(x,0,0) = \frac{Q}{2\sqrt{\pi}\, p L_p}\left(\frac{x}{L_p}\right)^{-3/2}, \qquad \text{(DR1)}$$

where L_p is a characteristic length scale given by $L_p = uK/p^2$. Figure 2A, for example, presents 2 plots of (DR1) with different sets of model parameters. These parameter sets were chosen to have different values of *K* and *p* but similar values of L_p. The similarity of the resulting plots indicates that the pattern of 2D dust deposition is not sensitive to particular parameters; it is only sensitive to the scaling parameter L_p. Therefore, raising the value of *K* and *p* simultaneously, as in Figure 2A, leads to solutions that are equally consistent with observations downwind of Franklin Lake playa. This nonuniqueness makes model calibration (in 2D or 3D) difficult. The model is best calibrated using wind-speed data to constrain *u* and *K* to the greatest extent possible, because these values can be independently determined using readily-available data. The deposition velocity, in contrast, cannot be readily determined. By constraining *u* and *K*, however, model results can then be run for a range of values of *p* to determine the value most consistent with observations.

Approximations and Limitations of the Numerical Model

The effects of complex downwind topography are only partially represented in the numerical model for several reasons. First, three-dimensional (3D) wind-flow patterns around topographic obstacles are not represented in the model. Including realistic wind-flow patterns would most likely increase the range of dust transport relative to the model of this paper for the same model parameters. The model approximates the effects of complex downwind topography using the downwind plume concentration calculated at the surface elevation $h(x,y)$ within the deposition term *pc*. In other words, the Gaussian plume (with deposition occurring on a flat surface) intersects the complex downwind topography.

The limitation of this approach can be understood by distinguishing between two types of mass loss that occur in natural plumes. In the first type, mass loss occurs because of "skin drag," in which lower wind speeds near the surface leads to dust fallout. In the second type (i.e. "form drag"), mass loss occurs because the plume intersects a topographic obstacle blocking the flow. This type of deposition is not perfectly effective, however, because most of the dust that intersects the topography is reflected back into the plume. In our model, mass loss occurs only because of the "skin drag" type of deposition due to the assumption of deposition on a horizontal ground surface.

The model results for Eagle Mtn. study area and for the simple test cases suggest that the model is capturing the effects of complex downwind topography despite the model approximation, but it should be emphasized that the model is not an exact solution. A more precise solution (but still neglecting 3D flow fields) would require a 3D finitedifference solution for the advection-diffusion-settling equation over complex topography. Smith (2003) has laid out a recipe for doing this using computationally-efficient Fourier transform methods. His approach will be adopted in future work. Importantly, Smith's (2003) method also allows for spatial variations in deposition velocity *p*. In nature, deposition velocity varies with the surface roughness (e.g. pavement development, vegetation cover). These effects can be included in the model using Smith's approach.

Additional Conclusions

Our results for Franklin Lake playa indicate that deposition rates decrease rapidly as a function of distance crosswind and downwind from playa sources. We began this study by hypothesizing that dust deposition rates would significantly decrease downwind over scales of about 10 km or more. We were surprised to find that deposition rates decrease much more rapidly – by a factor 2 within only 1 km. Although our results are specific to Franklin playa and Eagle Mountain, the pattern of downwind deposition depends on variables (i.e. wind speed *u* and deposition coefficient *p* (controlled by surface roughness)) that do not vary greatly in regions of similar vegetation cover. As a result, we believe that rapid downwind attenuation of dust deposition is likely to be a general feature of playas in the Basin and Range. Given that playas are typically separated by 10-20 km or more in the Basin and Range, our results imply that eolian deposition rates may vary by an order of magnitude or more depending on distance from nearby playas and prevailing winds. The strong heterogeneity of dust deposition inferred from our study may seem to be an obvious conclusion, but its implications for the evolution of desert surfaces have not yet been widely discussed in the literature. Studies that have documented the role of eolian deposition in pedogenic processes have generally emphasized temporal variability (e.g. higher dust transport rates in the Holocene compared with the Pleistocene) rather than spatial variability. Eolian deposition is known to be the primary driver of desert pavement formation, for example. One implication of our paper is that rates of desert pavement formation may vary by as much as an order of magnitude depending on position relative to dust sources. Our work suggests that distance from playa sources and prevailing winds are important variables that should be considered in order to better understand and quantify rates of desert surface and soil evolution.

Figure DR1. Type-example surfaces for Qa5-Qa2 on Eagle Mtn. piedmont. Qa5 (latest Pleistocene – early Holocene) exhibits bar-and swale topography and weak pavement and varnish development. Qa4 (late Pleistocene) exhibits strong to moderate pavement and varnish development with no bar-and-swale topography remaining. Qa3 (middle to late Pleistocene) appears similar to Qa4 in many respects (strong pavement and varnish development), but diffusive degradation of the surface has “crowned” the surface. Planar remants exist only on broad terraces of this unit. Qa2 (middle Pleistocene) exhibits disturbed pavement in many locations due to subsurface piping. Hillslope erosion has removed all planar remnants of this surface. The divide crests were sampled on this surface to minimize the impact of hillslope-erosional loss of eolian material.

References

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Waypoint (all UTM zone 11)	Easting	Northing	Age	silt thickness (in)	notes	silt thickness (cm)
027	0556040	4008797	Qa2	15		38.1
100	0556179	4009107	Qa2	6		15.24
107	0556131	4008924	Qa2	7		17.78
108	0556199	4008824	Qa2	4.5		11.43
110	0556259	4008726	Qa2	6.5		16.51
121	0556248	4008335	Qa2	5.5		13.97
122	0556389	4008349	Qa2	6		15.24
123	0556408	4008181	Qa2	4.5		11.43
140	0556376	4007014	Qa2	4		10.16
141	0556570	4007099	Qa2	4		10.16
142	0556717	4007145	Qa2	3		7.62
143	0556823	4007063	Qa2	3		7.62
144	0556950	4007067	Qa2	1.5		3.81
146	0557096	4007090	Qa2	3		7.62
148	0556216	4007021	Qa2	2.5		6.35
153	0556163	4007581	Qa2	5.5		13.97
157	0556062	4009164	Qa2	8		20.32
013	0556020	4007474	Qa3	7		17.78
016	0556170	4007221	Qa3	5		12.7
021	0555983	4008021	Qa3	8		20.32
022	0555931	4009136	Qa3	22		55.88
023	0555914	4009043	Qa3	19		48.26
026	0555896	4008942	Qa3	17		43.18
030	0555982	4008480	Qa3	10.5		26.67
032	0555924	4008323	Qa3	4.5		11.43
034	0555918	4008199	Qa3	9.5		24.13
035	0556024	4009274	Qa3	26.5		67.31
038	0556021	4009878	Qa3	7		17.78
039	0556119	0401009	Qa3	5		12.7
040	0556305	4010147	Qa3	26.5		67.31
041	0556142	4010200	Qa3	12		30.48
037b	0556182	4010003	Qa3	24		60.96
038b	0556284	4009920	Qa3	14		35.56
039b	0556214	4009975	Qa3	24		60.96
040b	0556149	4010093	Qa3	22		55.88
041b	0556093	4010146	Qa3	19.5		49.53
042	0556264	4010068	Qa3	9		22.86
045	0556311	4010147	Qa3	24.5		62.23
046	0556301	4010226	Qa3	13.5	close to road, anomalous?	34.29
047	0556234	4010220	Qa3	9.5	degraded	24.13
048	0556387	4010170	Qa3	32		81.28
049	0556379	4010129	Qa3	23.5		59.69
050	0556378	4010220	Qa3	30.5		77.47
051	0556372	4010264	Qa3	21		53.34
052	0556500	4010123	Qa3	26		66.04
053	0556594	4010085	Qa3	19.5		49.53
054	0556540	4010174	Qa3	12		30.48
055	0556555	4010338	Qa3	14.5		36.83
056	0556529	4010376	Qa3	17.5		44.45
057	0556593	4010267	Qa3	19		48.26
058	0556651	4010167	Qa3	16		40.64
059	0556681	4010105	Qa3	20		50.8
061	0556987	4009886	Qa3	8.5		21.59
062	0557053	4009912	Qa3	7		17.78
063	0557166	4009870	Qa3	10		25.4
064	0557287	4009746	Qa3	12		30.48
065	0557435	4009647	Qa3	9		22.86
066	0557582	4009594	Qa3	7.5		19.05
067	0557600	4009641	Qa3	11		27.94
068	0557627	4009723	Qa3	9		22.86
069	0557657	4009831	Qa3	7		17.78
070	0557709	4009939	Qa3	11		27.94
071	0557737	4010036	Qa3	11		27.94
072	0557735	4010187	Qa3	6.5		16.51
073	0557666	4010209	Qa3	5.5		13.97
075	0557488	4010186	Qa3	10		25.4
076	0557478	4010296	Qa3	8	veg. and ponding	20.32
077	0557432	4010454	Qa3	7.5	veg. and ponding	19.05
078	0557386	4010633	Qa3	14	veg. and ponding	35.56
079	0557095	4010558	Qa3	31	veg. and ponding	78.74
080	0557158	4010470	Qa3	12		30.48
081	0557174	4010381	Qa3	7.5		19.05
082	0557158	4010184	Qa3	22	veg. and ponding	55.88
083	0557146	4010183	Qa3	22	veg. and ponding	55.88
084	0557162	4010070	Qa3	19		48.26
085	0557053	4010096	Qa3	13		33.02
086	0556929	4010115	Qa3	14		35.56
087	0556854	4010275	Qa3	26		66.04
088	0556715	4010299	Qa3	24		60.96
090	0555966	4009603	Qa3	6.5		16.51
091	0556060	4009553	Qa3	8		20.32
092	0556151	4009451	Qa3	9		22.86
093	0556158	4009377	Qa3	14		35.56
094	0556037	4009407	Qa3	10		25.4
095	0555877	4009447	Qa3	8		20.32

096	0555876	4009519	Qa3	1	Very degraded	2.54
097	0555861	4009297	Qa3	14		35.56
098	0555964	4009307	Qa3	24		60.96
099	0556092	4009313	Qa3	14		35.56
103	0555839	4009141	Qa3	5		12.7
104	0555829	4009058	Qa3	5		12.7
105	0555828	4008943	Qa3	18		45.72
106	0555993	4008963	Qa3	11.5		29.21
112	0556291	4008511	Qa3	5.5		13.97
116	0555880	4008457	Qa3	26		66.04
119	0555990	4008319	Qa3	6		15.24
120	0556106	4008313	Qa3	8		20.32
124	0556237	4008151	Qa3	4.5		11.43
125	0556152	4008182	Qa3	5		12.7
126	0556129	4008130	Qa3	8		20.32
127	0556019	4008173	Qa3	12		30.48
128	0555847	4008212	Qa3	10		25.4
129	0555826	4008118	Qa3	6		15.24
130	0556012	4008032	Qa3	9		22.86
131	0556182	4008035	Qa3	8		20.32
132	0556337	4008034	Qa3	6		15.24
133	0556226	4007972	Qa3	6.5		16.51
134	0556218	4007785	Qa3	5		12.7
135	0556014	4007644	Qa3	11		27.94
136	0556038	4007523	Qa3	9		22.86
137	0556177	4007481	Qa3	8.5		21.59
138	0556272	4007484	Qa3	11.5		29.21
139	0556101	4007427	Qa3	7		17.78
150	0556250	4006868	Qa3	6.5		16.51
155	0555888	4009048	Qa3	12		30.48
156	0556035	4009117	Qa3	9		22.86
158	0556062	4009524	Qa3	12		30.48
159	0555874	4009594	Qa3	7		17.78
162	0556178	4009640	Qa3	11.5		29.21
164	0556078	4009687	Qa3	6		15.24
165	0555971	4009903	Qa3	7.5		19.05
166	0556006	4009984	Qa3	8		20.32
167	0556095	4010024	Qa3	10	veg. and ponding	25.4
168	0556750	4010172	Qa3	24	veg. and ponding	60.96
169	0557038	4010309	Qa3	10	veg. and ponding	25.4
014	0556079	4007337	Qa4	7		17.78
017	0556085	4007167	Qa4	7.5		19.05
019	0555998	4007729	Qa4	7		17.78
024	0555936	4009061	Qa4	7		17.78
029	0555997	4008617	Qa4	5.5		13.97
031	0555922	4008398	Qa4			0
033	0555926	4008284	Qa4	4.5		11.43
037	0556063	4009622	Qa4	5.5		13.97
043	0556294	4010071	Qa4	8.5		21.59
060	0556993	4009844	Qa4	0		0
074	0557617	4010236	Qa4	4		10.16
089	0555881	4009651	Qa4	12		30.48
101	0556160	4008975	Qa4	11		27.94
102	0556077	4009066	Qa4	5		12.7
113	0555886	4008610	Qa4	6		15.24
115	0555872	4008494	Qa4	11		27.94
117	0556014	4008428	Qa4	6		15.24
118	0555922	4008398	Qa4	11		27.94
149	0556206	4006833	Qa4	4		10.16
151	0556103	4007033	Qa4	16	located at base of large Qa2	40.64
152	0556164	4007109	Qa4	21	located at base of large Qa2	53.34
154	0555942	4008686	Qa4	8		20.32
160	0556123	4009600	Qa4	12		30.48
161	0556193	4009555	Qa4	9		22.86
163	0556120	4009675	Qa4	10		25.4
170	0557324	4010179	Qa4	8		20.32
171	0557357	4010072	Qa4	17		43.18
172	0557370	4009985	Qa4	11		27.94
015	0556142	4007265	Qa5	1.5		3.81
018	0556012	4007555	Qa5	4		10.16
020	0556011	4007853	Qa5	1.5		3.81
025	0555939	4009070	Qa5	1.5		3.81
028	0556014	4008744	Qa5	4		10.16
036	0556006	4009347	Qa5	3		7.62
044	0556294	4010089	Qa5	1		2.54