INVESTIGATING TEMPROAL AND SPATIAL SCALES OF SEDIMENT APRON BEHAVIOR IN THE MOJAVE DESERT

A Thesis Progress Report Presented

By

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to

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The following members of the Thesis Committee have read and approved this document before it was circulated to the faculty:

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****Plates 1-3 are in the Map Room****

Introduction

Little is known about the behavior of large (>20 km^2) aprons of sediment that extend from inselbergs in the Mojave Desert. Slow surface processes and remote locations have hindered the investigation of different temporal and spatial scales of sediment apron behavior. Advances in the measurement of cosmogenic isotopes make it possible to characterize the long-term behavior of such surfaces, over both large and small spatial scales. Recent advances in the precision of global positioning systems (GPS) allow measurement of small-scale, short-term geomorphological changes (~1 cm).

I am characterizing different temporal and spatial scales of sediment apron behavior near the Iron and Granite Mountains (Plate 1), southern Mojave Desert. From 1942-1944, the US Army built temporary tent cities, or base camps, in these locations. The camps housed up to 20,000 troops, along with numerous wheeled and tracked vehicles. When the army left the area, most berms created during road building and most walkway and tent rock alignments remained. One can assume that some drainage networks were obliterated during the occupation of the army by the constant foot and heavy vehicle traffic. In the 54 years since the evacuation, the drainage networks have begun to reestablish with minimal subsequent human disturbance (Nichols, 1998). This is a unique location to study the short-term, small-scale geomorphic changes on arid alluvial surfaces.

Long-term rates of sediment transport across sediment aprons are unknown. Although, such transport times are site specific, the technique that I have developed could easily be applied other locations. This is the first investigation of sediment residence and transport times using cosmogenic isotope data.

Work Completed

I completed my fieldwork in May 1998 and I am presently finishing the chemical and isotopic analyses. The fieldwork consisted of two parts: 1) collecting forty sediment samples for cosmogenic isotope analysis to in order to characterize the long-term behavior of the Granite and

Iron Mountain sediment aprons, and 2) mapping eighteen, 3600 m^2 plots to characterize small-scale sediment apron behavior.

Laboratory work involved sieving sediment samples, separating quartz, determining percent carbonate in soil pit samples, and quantifying cosmogenic isotope abundance using the accelerator mass spectrometer at Lawrence Livermore National Laboratory (LLNL). Analytical methods involved reduction of survey data, map drafting, and statistical analysis of channel parameters such as depth, width, and drainage density.

Cosmogenic Isotope Sample Collection

In order to characterize the long-term behavior of the Granite and Iron Mountain sediment aprons, I collected three types of samples for cosmogenic isotope analysis 1) valley samples, 2) transect samples, and 3) soil pit samples (Table 1). Valley and transect samples characterize the large-scale sediment apron behavior. The soil pit profiles will provide data for better understanding small-scale sediment apron behavior.

Valley Samples	**Transect Samples**		**Soil Pit Samples**	
Iron Mountain	Iron Mountain	Granite Mountain	Iron Mountain (depth cm)	
IMV1	IMT-0	GMT-0A	Pit 1 0-10	Pit 2 0-14
IMV2	IMT-0 FAN*	GMT-0B	Pit 1 10-20	Pit 2 14-28
IMV3	IMT-1	GMT-1	Pit 1 20-30	Pit 2 28-40
Granite Mountain	IMT-1 CHAN**	GMT-2	Pit 1 30-40	Pit 2 40-50
GMV1	IMT-1 CRIT***	GMT-3	Pit 1 40-50	Pit 2 50-60
GMV2	IMT-1 TERR****	GMT-4	Pit 1 50-66	Pit 2 60-71
GMV3	IMT-2		Pit 1 66-76	Pit 2 71-80
	IMT-3		Pit 1 76-86	Pit 2 80-90
	IMT-4			
	IMT-4 CHAN**			
	IMT-4 CRIT***			
	IMT-4 TERR****			

Table 1: List of Cosmogenic Isotope samples. Numbers after hyphens indicate kilometers from Transect 0.

* Sample taken from older abandoned alluvial fan
** Sample of channel sediment
*** Sample of animal burrow sediment
**** Sample of terrace sediment

Valley Samples

The valley samples are important for two reasons. First, cosmogenic isotope analysis quantifies the bedrock erosion rate, and thus sediment yields, of the Iron and Granite Mountains. Second, the samples provide a proxy for initial abundances of cosmogenic ^{10}Be and ^{26}Al in quartz as sediment grains enter the apron. Drainage basin sediment yields, and the initial isotope abundances are important to determine sediment transport rates and sediment residence times.

I collected three sediment samples from two valleys exiting large drainage basins for both the Iron and Granite Mountains. Each sample is an amalgamation of surface sediment collected from a single channel at the sediment apron/rangefront interface.

Transect Samples

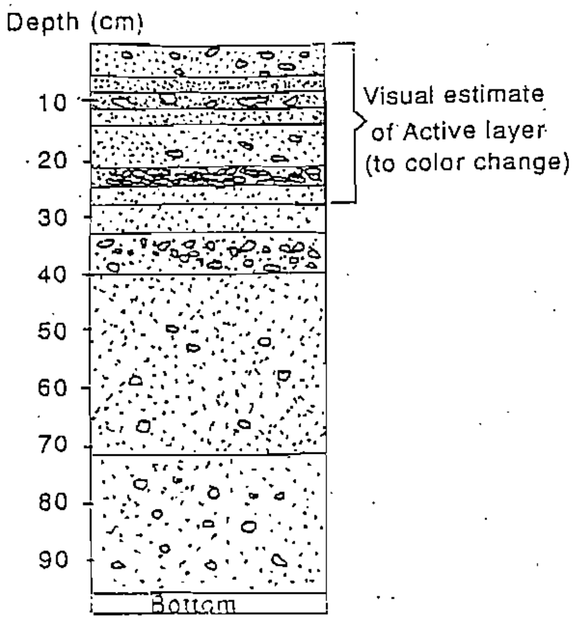
I walked a series of five, four-kilometer long transects at one-kilometer intervals away from both the Granite and the Iron Mountain ranges (Plate 1). Along each transect I used a hand-held GPS (Garmin 12) to locate sampling stations approximately 200 m apart. I collected equal amounts of surface sediment at each station. The uncertainty of the GPS randomized collection stations within a 20-m radius. At the end of each transect I mixed all sub-samples to make one amalgamated sample.

Sediment for each transect was collected from three geomorphic features: 1) sediment from channel bottoms 2) sediment from topographically higher terraces and 3) sediment excavated by animals (burrow tailings). To investigate the different cosmogenic isotope contribution of each feature, I collected separate amalgamated samples for each category. At each 200 m interval along IMT-1 and IMT-4, I collected sediment from the nearest terrace, channel, and burrow tailing pile.

Soil Profiles

I am using two, ~1-m deep soil pits to characterize the sediment apron as a function of depth. The pits were hand dug with a spade to refusal. I used a pry bar and a sledgehammer to continue to a depth of approximately one meter.

I visually logged each layer in the pit describing texture, grain size, cementation and color, and I collected eight samples from each soil pit (Figure 1). I used a continuous sampling method, insuring that all areas of each layer were equally represented.



Therefore... not stirred

0-5 cm: 5 mm crust and gravel lag on surface underlying silty sand with some clasts to 2 cm. Few distinct layers. White to gray in color. 10 YR 6/4

5-21 cm: Stratified medium sand and gravel to 1 cm, some silt. 10 YR 6/4

21-24 cm: Medium to coarse gravel layer 3 to 4 clasts thick, some silt. 10 YR 7/4

24-33 cm: Homogenous, medium to coarse sand with very fine interbeds, little silt. Color change from 10 YR 7/4 to 10 YR 6/6 at 28 cm.

33-40 cm: Gravel with silty sand matrix. Homogenous- no real layers. Sharp contact with B soil horizon at 40 cm. 10 YR 6/6

40-71 cm: Homogenous silt and fine gravel. Few clasts over 1 cm. Moderately cemented. Matrix does not react to HCl, but undersides of few clasts react weakly. Red-brown 7.5 YR 5/6

71-96 cm: Homogenous, cemented, silt to fine gravel dominantly medium sand. Matrix reacts moderately to HCl. 10YR 5/6

Figure 1: Stratagraphic log of Soil Pit 2.

Small-scale Geomorphology

I used a Trimble 4400 GPS system to map six, 3600 m^2 control plots and twelve, 3600 m^2 disturbed plots (Plate 2). The data are precise on the centimeter scale.

Control Plots

I chose the locations of the control plots randomly by dropping pebbles onto my field map, until six locations on the Iron Mountain sediment apron satisfied the following criteria; the sediment source was the Iron Mountains and the plot locations were outside of the former Camp Iron Mountain.

I determined the plot boundaries by using a Pentax total station to delineate 60 m orthogonal sides. I surveyed the topography using approximately a five-meter grid spacing. I flagged boundaries of all channels within each plot, and surveyed the top and bottom of the left and right banks along the length of each channel.

After surveying each plot, I downloaded the data into Surfer® software and plotted the top bank, boundary, and other notable points. After making a map, I field checked each plot for accurate channel locations and notable observations before removing the channel boundary flags.

Walkway Plots

I used the following criteria to choose the walkway plot locations. The plots were within the former Camp Iron Mountain; visible rock alignments were present and roads were absent. I chose the plot locations by walking within the camp until I could see that the rock alignments extended approximately 80 m in all directions. To minimize bias, I walked 20 additional steps, in the same direction, before setting up the plot boundaries. I surveyed and field checked the walkway plots using the same techniques as the control plots. In addition, I surveyed all rock outlines of walkways.

Road Plots

Road plots were located within the former Camp Iron Mountain limits; where few or no rock alignments were present, where the road berm formed the up-gradient boundary, and where no other roads were present. I chose the road plots by walking along a road until I reached a spot where there were no rock alignments. I surveyed and field checked the road plots using the same techniques as the control plots.

Laboratory Procedures and Data Reduction

In June, I began laboratory work. I sieved all 40 of my sediment samples to: 1) obtain grain size distributions as a function of distance away from rangefront and as a function of depth in the soil pits, and 2) separate out the 0.5 – 1.0 mm fraction for the cosmogenic isotope analysis. I selected the 0.5 –1.0-mm grain size to minimize the possibility of analyzing wind blown sediment from sources other than the Iron or Granite Mountains.

Quartz separation

Over the summer, I separated pure quartz (<100 ppm Al) from each of the 40 sediment samples. I used sequential acid etches of 1% HF and 1% HNO_3 to dissolve all but quartz and a few heavy minerals, which were later removed by density separation. The acid treatment dissolved outer layers of the quartz grains that could contain ^{10}Be produced in the atmosphere.

Initial Findings of Grain Size Distributions

I have investigated the distribution of grain size both as a function of distance away from the rangefront, and as a function of depth (Plate 3a-e). The pit data and the grain size data do not show increasing or decreasing grains sizes as a function of depth (Plate 3a-d). Each, transect was composed of differing numbers of terrace, channel, animal burrow (critter), channel bank and road collection sites (Table 2). The grain size distributions for 100 % channel, 100 % critter, and 100 % terrace samples (Plate 3e) show that terrace samples contain more fine material than channel and critter burrow samples. These results suggest that, for each transect, the percentage of terrace collection sites dominates the fine fraction percentage, while the percentage of channel collection sites dominates the gravel fraction.

Transect	IMT-0	IMT-1	IMT-2	IMT-3	IMT-4	GMT-0A	GMT-0B	GMT-1	GMT-2	GMT-3	GMT-4
Terrace	11	13	13	9	15	13	10	12	12	11	11
Channel	5	4	6	10	5	5	7	8	8	6	6
Bank	0	1	0	0	0	2	1	0	0	2	2
Road	0	0	1	1	0	0	1	0	0	1	1
Burrow	0	0	0	0	0	0	1	0	0	0	0
Fan	4	2	0	0	0	0	0	0	0	0	0

Table 2: Distribution of collection site classifications

Initial findings of short-term, small-scale behavior of sediment apron

To date I have calculated the average depths, widths, areas, and volumes of all channels within each plot (Table 3). I calculated the average depth of the channels by subtracting bottom bank data from top bank data. I used the Pythagorean theorem to calculate the width of each channel. I used Digitize® software to calculate the channel area within each plot.

are these SE or SD?

Average channel depths range from 6.9 ± 1.5 cm for road plots to 8.8 ± 1.2 cm for control plots. Average channel widths range from 0.94 ± 0.31 m for road plots to 2.02 ± 0.29 m for control plots. The results suggest that channels in undisturbed control plots, representative of drainage network long-term behavior, are wider and deeper than those in disturbed plots. From the data, I infer that the disturbed drainage networks have not fully recovered in the 54 years since camp evacuation. Many berms within the camp are still intact, and concentrate the runoff to a few channels. The preliminary data suggest that building berms and roads on sediment aprons affects drainage network morphology decades after berm maintenance has ceased.

Plot Number	Channel depths (m) Control	Walk	Road	Channel widths (m) Control	Walk	Road	Channel Area (m^2) Control	Walk	Road
1	0.107	0.065	0.090	2.42	1.02		1064	287	1160
2	0.074	0.084	0.061	2.02	1.90	1.15	477	302	630
3	0.098	0.055	0.058		1.34	0.88	603	361	314
4	0.079	0.071	0.076	2.10	1.43	1.36	1100	547	258
5	0.082	0.061	0.051	1.94	1.09	0.63	765	307	152
6	0.088	0.087	0.077	1.63	1.40	0.69	394	787	427
Average	**0.088**	**0.071**	**0.069**	**2.02**	**1.36**	**0.94**	**733**	**432**	**490**
Standard deviation	**0.012**	**0.013**	**0.015**	**0.29**	**0.31**	**0.31**	**297**	**199**	**367**

Table 3: Channel depths, widths, and areas for all plots.

<u>Initial findings of long-term, large-scale behavior of sediment apron</u>

I have completed the ^{10}Be analysis of seven Iron Mountain samples. The data show that there is a positive linear correlation between distance from the rangefront and the abundance of ^{10}Be (Figure 2). The data shows that as sediment passes through each transect there is a linear accumulation of ^{10}Be as a function of distance away from the rangefront. This implies the transport processes are systematic along the length of the sediment apron.

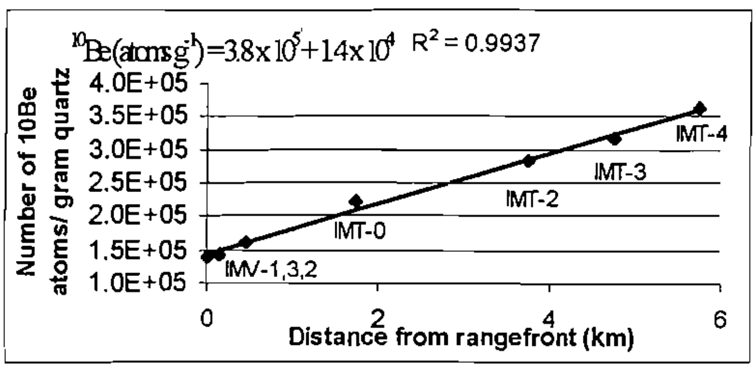


Figure 2: ^{10}Be abundances as a function of distance from rangefront.

Currently, I have three independent measures of the active layer (Nichols, 1998). These measurements are the average channel depth (~9 cm), and two visual estimates from the soil pits (20 cm and 28 cm). By using these estimates I can narrow in on the sediment transport time (Figure 3). Currently, some researchers believe that ^{10}Be production rates are closer to 5 atoms g^{-1} y^{-1} than 6 atoms g^{-1} y^{-1} (Clark et. al., 1995 and Stone, 1998). The fastest and slowest travel time estimates are different by less than a factor of two!

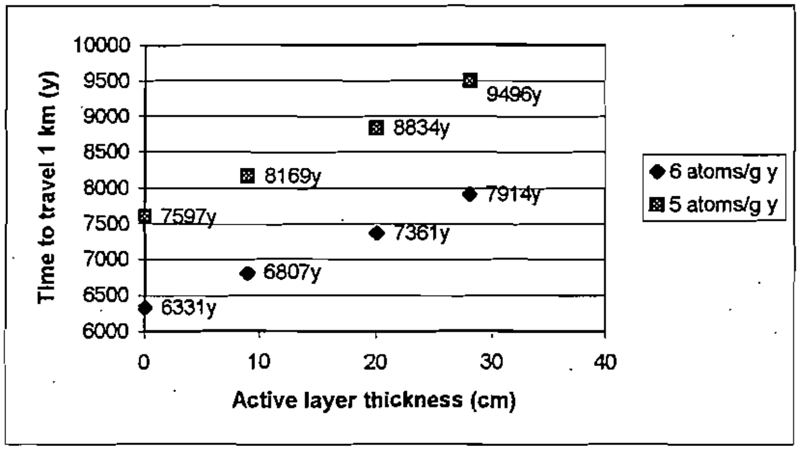


Figure 3: Graph of travel times as a function of active layer thickness for ^{10}Be production rates of 5 atoms g^{-1} y^{-1} and 6 atoms g^{-1} y^{-1}.

Sediment is likely transported down the apron by stream transport, the only transport process that can uniformly cover large areas. Bioturbation, a second possibility, is more prevalent near the rangefront where there is more vegetation and moisture. Also, animals only move sediment to the surface. The low sediment apron slope and the small mounds of sediment cannot account for significant lateral transport of sediment after animal burrowing.

Work Remaining

Remaining data acquisition involves finishing the cosmogenic isotope analyses. I will recalculate the initial results of all channel statistical parameters within the plots and I will perform a statistical analysis of these results. I will use Stella to model the cosmogenic isotope data for the soil pits to show the active layer thickness. I will model the transect data to show residence time and transport rates of sediment across the apron.

Estimated Timetable

September 1998 – October 1998: Complete statistical analysis of plots

October 1998: Present poster of short-term, small-scale geomorphology at National GSA 1998

November-December 1998: Finish cosmogenic isotope analysis at LLNL

November-December 1998: Start to write paper for journal as part of thesis

Sometime in 1999: Hand in thesis and defend!

Clark, Douglas H., Bierman, Paul R., and Larsen, Patrick. 1995. *Improving in Situ Cosmogenic Chronometers.* Quaternary Research **44**, p. 367-377.

Nichols, Kyle K. 1998. *Investigation of different temporal and spatial scales of sediment apron behavior in the Mojave Desert: A cosmogenic isotope approach.* Thesis Proposal to the University of Vermont, unpublished, 12pp.

Stone, John O., Ballantyne, Colin K., and Fifield, L. K. 1998. *Exposure dating and validation of periglacial weathering limits, northwest Scotland.* Geology **26**, p. 587-590.