

ABSTRACT

I will analyze cosmogenic ^{10}Be and ^{26}Al nuclide activities in three grain-sizes in a 2m-deep soil pit located on the Kofa Mountain Piedmont to establish the timing of deposition on a stable desert piedmont at Yuma Proving Grounds (YPG) in Yuma, AZ. I will use the resulting data to reconstruct the surface history, deposition rates, and periods of surface stability of the Kofa Mountain Piedmont. Presently, the piedmont surface is stable (neither grading nor eroding) as indicated by the presence of varnished interlocking desert pavements above an Av (vesicular) soil horizon. By deciphering the timing of deposition and surface stability, we will better understand piedmont process in relation to climate change.

INTRODUCTION

Alluvial, aeolian, hillslope, and biogenic processes dominate sediment transport in arid climates (Wells et al. 1995). Alluvial processes refer to erosion and deposition of sediment by water processes. Though scarce in the Sonoran Desert, water forms ephemeral channels that fill during rainstorms and move considerable amounts of sediment. Aeolian sediments that are fine-grained can travel great distances (cm to km) in the wind. Hillslope processes are responsible for generating sediment from mountain bedrock. Finally, biogenic processes refer to the flora trapping airborne sediments and fauna that mix and move sediment. By considering these processes in concert one can understand better the sediment transport in arid regions.

Although sediment transport depends on many individual processes, sediment on piedmonts is dominated by alluvial processes. My study focuses on the rate and timing of alluvial processes modifying the Kofa Mountain Piedmont in the Sonoran Desert located in the arid southwestern United States (Figure 1). Much of the southwestern United States consists of mountain ranges separated by extensive drainage basins.

Piedmonts, the low-sloping features that extend from the base of mountains, can be landforms characterized by sediment deposition and/or landforms where sediment is transported across the surface. My study will provide new insight into the long-term processes that have shaped mountain belts.

The Kofa Mountain Piedmont exhibits several indications of surface stability. The accumulation of aeolian fines (clay and silt) results in the formation of an Av (vesicular) soil horizon and rock varnish (Liu and Broecker, 2000). Vesicles within the

would inevitably become the “born at the surface” pavement around my soil pit. Thus, incised channels play an important role in the depositional history and eventual formation of desert pavement of the Kofa Mountain Piedmont. By better quantifying the timing of deposition and stability of the subsurface, one can better quantify the rate of pavement formation.

Cosmogenic Nuclides:

Cosmogenic nuclide analysis is a relatively new and increasingly valuable technique used in geomorphology. Aside from soil pits, cosmogenic nuclides have been measured in order to date marine terraces (Perg, 2001), landscape stability (Bierman, 1994), and upland erosion (Beirman and Steig, 1996, Clapp et al., 2001). Cosmogenic ^{10}Be and ^{26}Al nuclides are produced from secondary cosmic rays (particularly high-energy neutrons) that enter our atmosphere and interact with oxygen and silicon respectively. Therefore, quartz is an ideal target material. Production (within quartz grains) of these nuclides decreases exponentially with depth (Lal and Arnold 1985) and have minimal production at depths $>3\text{m}$ from the Earth’s surface (Figure 6). At the surface of the Earth, ^{26}Al and ^{10}Be nuclides are produced at a ratio of 6:1 respectively. ^{26}Al nuclides have a half-life of 7.0×10^5 years and ^{10}Be nuclides have a half-life of 1.5×10^6 years. Since production is minimal at depths >3 m, decay of the nuclides is faster than production. Given sufficient time ($>100,000$ yrs.) the activity of ^{26}Al will be less (due to a shorter half-life) than the activity of ^{10}Be for deeply buried sediments and the $^{26}\text{Al}/^{10}\text{Be}$ ratios will deviate from 6/1. Therefore, by measuring both nuclides, $^{26}\text{Al}/^{10}\text{Be}$ in quartz grains can yield the near-surface history of the quartz-bearing soils.

The implication of different nuclide activities in varying grain sizes and surface processes is subject to debate. For example, denudation rates in tropical Puerto Rico show that

a surficial system (Ritter et al., 1978). Since soil development is related to surficial processes, soils provide a context (or constraints) to produce quantitative piedmont-process models based cosmogenic nuclides.

Cosmogenic nuclide data offers many insights to landscape evolution over the 10^3 to 10^5 year time scale (Bierman, 1994). The rates at which nuclide bearing sediments are produced in drainage basins that move along desert surfaces, such as piedmonts, determines the nuclide activity within sediments upon final deposition. Most cosmogenic nuclide studies measure activities in rock to determine exposure age (Nichols et al., In prep) and bedrock erosion rates (Clapp et al., 2002). Recent studies have measured nuclide activity in sediment to determine drainage basin-wide erosion rates (Clapp et al, 2001, 2002). Applying this technique to the Kofa Mountain Piedmont includes not only the sediment generation history, but also the transportation history across the piedmont to the pit location. In drainage basins, the abundance of cosmogenic nuclides in sediment exiting a basin is inversely related to the rate at which the basin is eroding (Bierman and Steig 1996), thus high erosion rates have low nuclide activities.

Cosmogenic nuclide activity is used to create models of erosion rates along piedmonts and throughout drainage basins (Bierman and Steig, 1996, Nichols et al. 2002). As sediment exits the basins the nuclide activity in alluvial sediments increases as the sediment is transported down the piedmont and away from the mountain (Nichols et al. 2002). After deposition, continued production of nuclides creates a unique nuclide signature at depth that can be modeled to estimate the depositional history of the piedmont (Nichols et al., 2002, Phillips et al., 1998, Perg et al., 2001, Anderson et al., 1996).

At the Kofa Mountain Piedmont, grain size varies throughout the soil profile (fine silt and sand to cobble). Some units with large grain sizes might represent debris flow deposition while other layers with better-sorted grains might represent fluvial deposition.

Mass Spectrometry (AMS) to measure the $^{26}\text{Al}/^{10}\text{Be}$ ratios. These data will be used to construct a numerical model to quantify piedmont history at YPG.

EXPECTED OUTCOMES

I do not know if the analysis of different grain sizes will result in different nuclide activities. Analyzing various grain sizes for each soil section, however, will provide more information about sediment transport and deposition processes of desert piedmonts. By understanding the depositional processes and the surface stability of the Kofa Mountain Piedmont I will be able to constrain the formation and timing of desert pavements.

TIMELINE

- December 15-16, 2002: samples collected from McDonald pit YPG Yuma, AZ
- January 28 – February 5, 2003: 11 samples (22 bags, ~1 gal) dry sieved into 7 grain sizes (> 4000 μm , 1000 – 4000 μm , 841-1000 μm , 500 – 841 μm , 250 - 500 μm , 125 – 250 μm , and < 125 μm)
- February 6 – April 4, 2003: >4000 μm from each of 11 samples crushed and then sieved into 3 new grain sizes (> 841 μm , 250 – 841 μm , and < 250 μm)
- April 6, 2003: Samples > 4000 (250 - 841) μm , 500 – 841 μm , and < 125 μm for each of the 11 sample sections were submitted to UVM laboratories for HCl etching and cosmogenic ^{10}Be and ^{26}Al

REFERENCES

Anderson, R.S., Repka, J.L., Dick, G.S., 1996, Explicit treatment of inheritance in dating depositional surfaces using in situ ^{10}Be and ^{26}Al : *Geology*, v. 24, no. 1, p. 47-51.

Bierman, P.R., 1994, Using in situ produced cosmogenic isotopes to estimate rates

- McFadden, L.D., Wells, S.G., and Jercinovich, M.J., 1987, Influence of eolian and pedogenic processes on the origin and evolution of desert pavements: *Geology*, v. 15, p. 504-508.
- Nichols, K.K., Bierman, P.R., Hooke, R.LeB., Clapp, E.M., and Caffee, M., 2002, Quantifying sediment transport on desert piedmonts using ^{10}Be and ^{26}Al : *Geomorphology*, v. 45, p. 105-125.
- Nichols, K.K., Bierman, P.R., Eppes, M.C., Caffee, M., Finkel, R., and Larsen, J., (In prep), Deciphering the Late Pleistocene and Holocene History of the Complex Chemehuevi Mountain Piedmont Using ^{10}Be and ^{26}Al : *The American Journal of Science*.
- Nichols, K.K., Bierman, P.R., Caffee, M., and Finkel, R., (In prep), Revisiting the age of the Blackhawk: Landslide dating using ^{10}Be and ^{26}Al : *California Geology*.
- Perg, L.A., Anderson, R.S., and Finkel, R.C., 2001, Use of a new ^{10}Be and ^{26}Al inventory method to date marine terraces, Santa Cruz, California, USA: *Geology*, v. 29, no. 10, p. 879-882.
- Phillips, W.M., McDonald, E.V., Reneau, S.L., and Poths, J., 1998, Dating soils and alluvium from the Pajarito Plateau, New Mexico, USA: *Earth and Planetary Science Letters*, v. 160, p. 209-223.
- Ritter, D.F., Kochel, R.C., and Miller, J.R. Geomorphic Significance of Soils: Process Geomorphology, McGraw Hill, 1978, p. 73.
- Wells, S.G., McFadden, L.D., Poths, J., and Olinger, C.T., 1995, Cosmogenic ^3He surface-exposure dating of stone pavements: implications for landscape evolution in deserts: *Geology*, v.23, no.7, p. 613-616.

FIGURE CAPTIONS

Figure 1. Yuma Proving Grounds (YPG) is located in southwestern Arizona in the Basin and Range YPG is the horseshoe-shaped outline. My soil pit is located in the area marked with the small circle inside the Kofa Range.

Figure 2A. Two meter-deep soil pit located on the Kofa Mountain piedmont. The soil pit is situated within a broad, varnished desert pavement. The presence of an incised channel in the background indicates occasional erosion down the piedmont.

Figure 2B. Close-up of the soil pit showing sample locations from the 11 depth sections.

Figure 3. An example of an Av (vesicular) soil horizon. Vesicles are above the white line drawn on the sample.

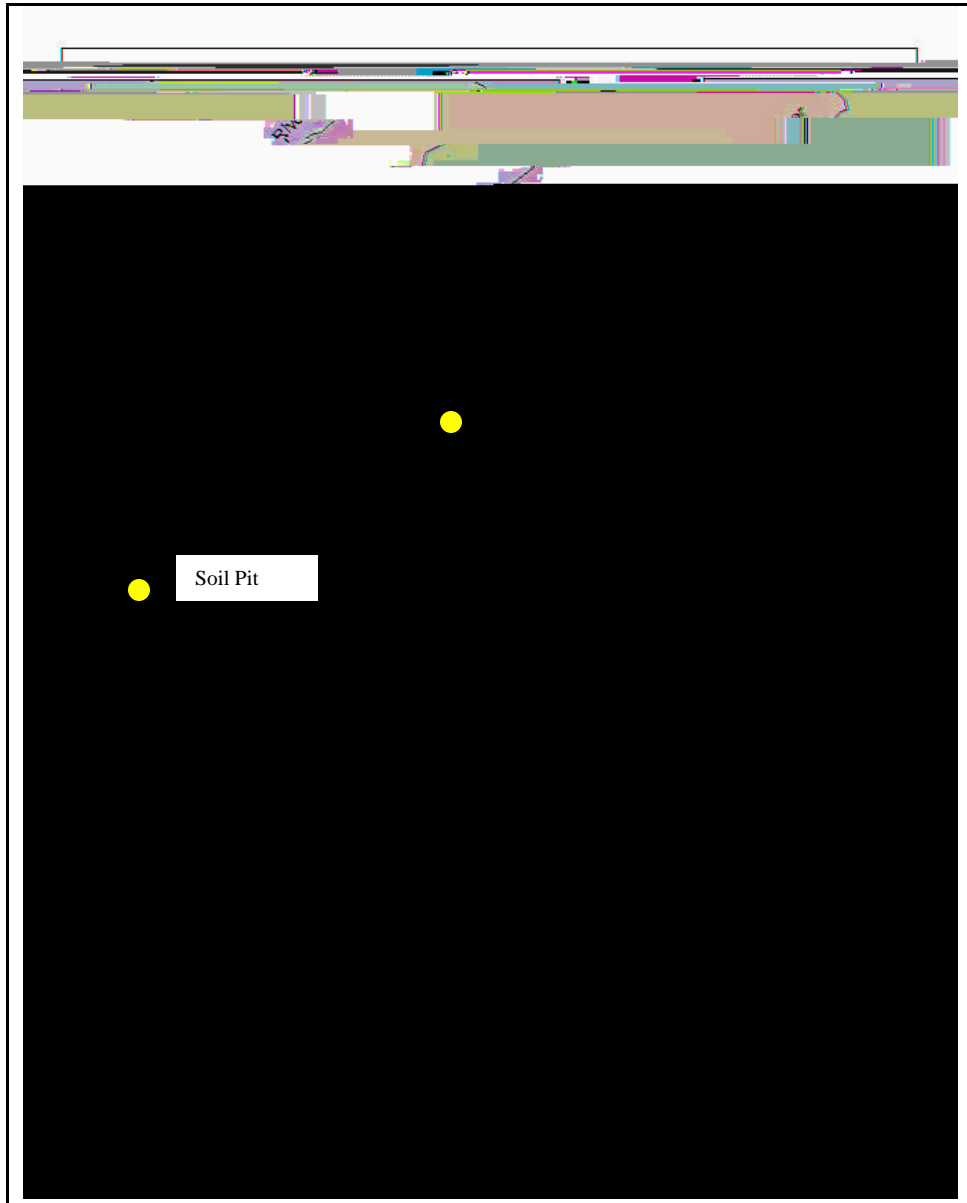
Figure 4. The rock varnish present on the desert pavement at YPG. Varnish is the result of clay-rich aeolian sediments interacting with exposed surface clasts. Note the dark color represents top of clast exposed sub-aerially.

Figure 5A. A top-down view of the desert pavement present on the Kofa Mountain piedmont. Note the darkly varnished interlocking clasts.

Figure 5B. Cross-Section view of the desert pavement at my soil pit. This photograph displays the 2 cm-thick pavement formed above the 8cm Av soil horizon. Also note the absence of clasts within the 8cm-thick Av section.

Figure 6. The production of cosmogenic ^{10}Be and ^{26}Al nuclides decreases exponentially with depth from the surface of the Earth.

FIGURES



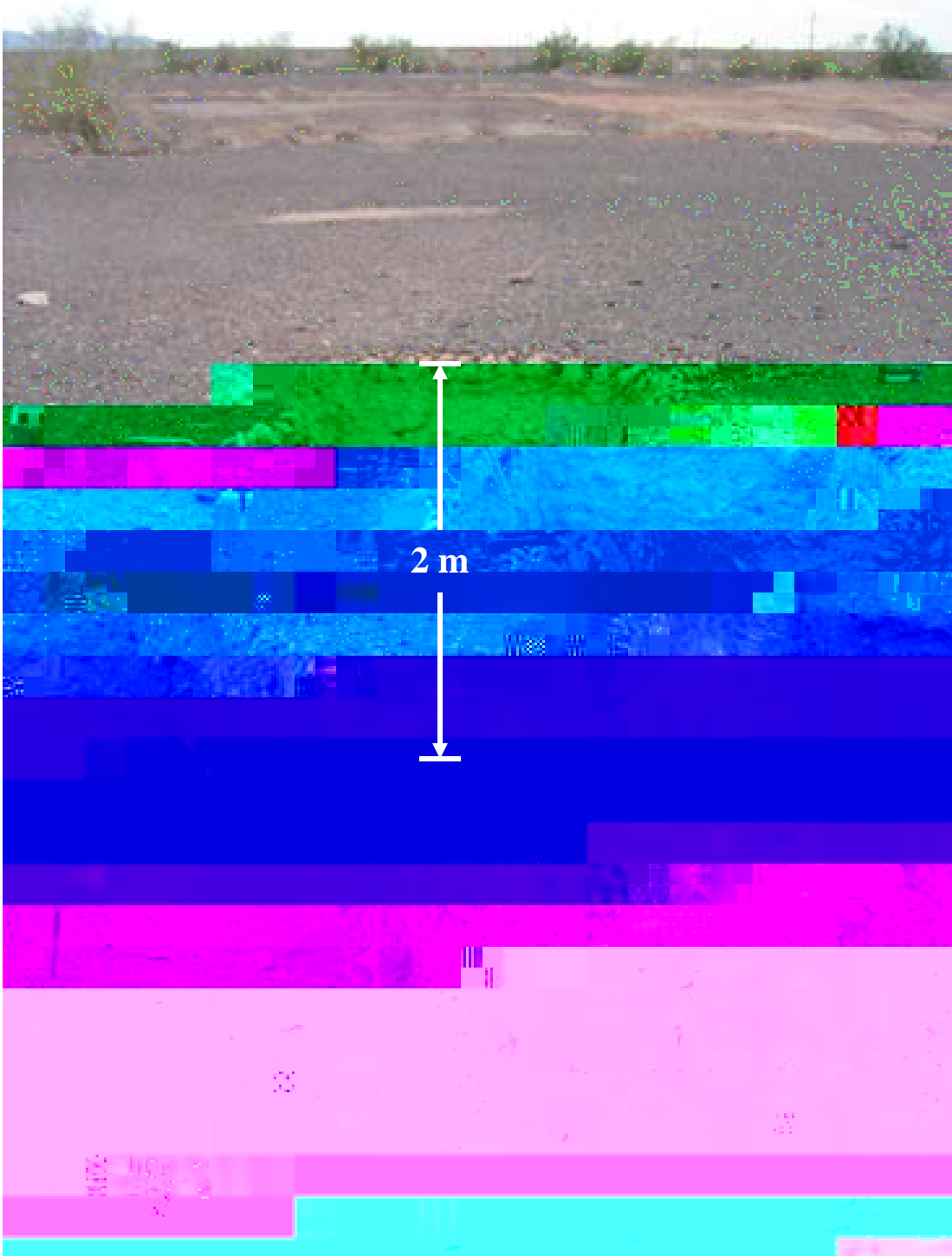


Figure 2A

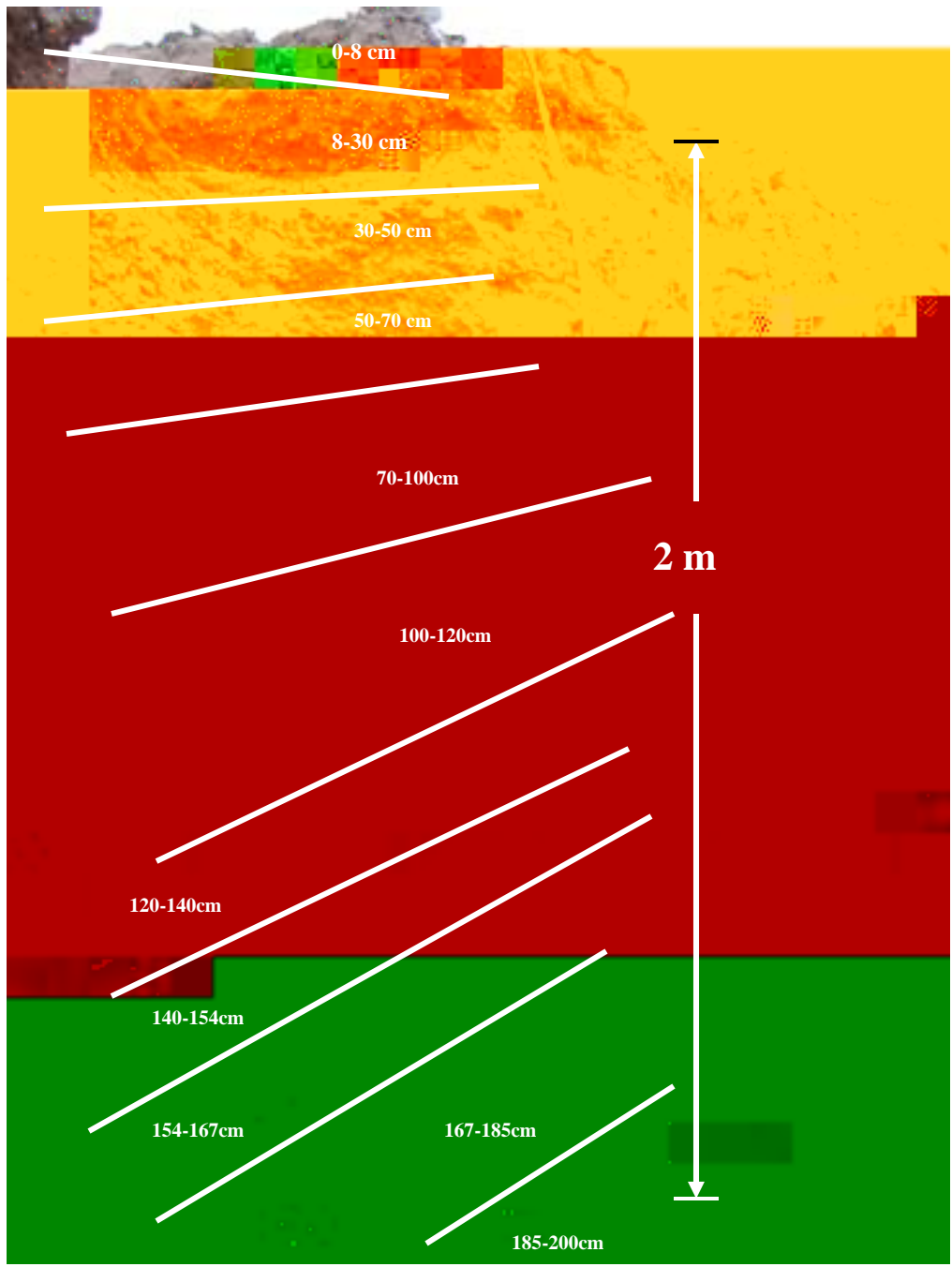


Figure 2B



Figure 3

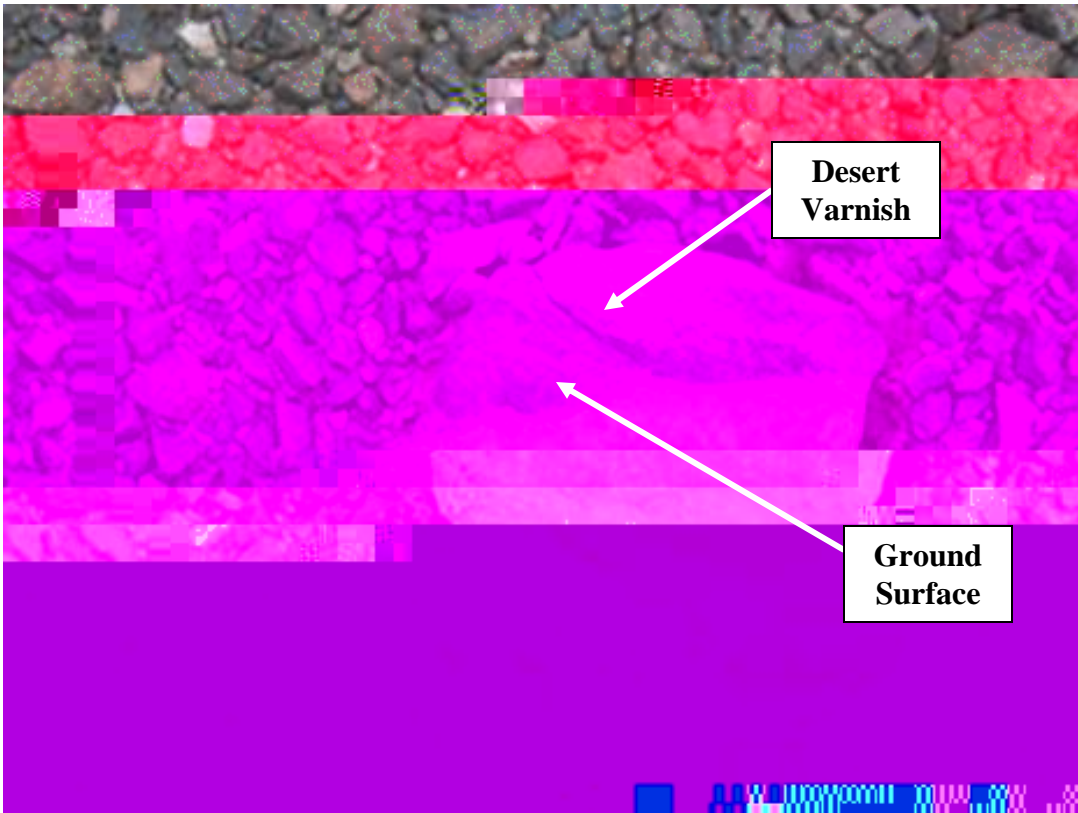


Figure 4



Figure 5A



Figure 5B

