Quantifying Surface Roughness and Geologic Composition of Alluvial Fans in Death Valley as Analogs for Planetary Landforms

Jake Draper (jrd585@nau.edu)
Mentored by Anthony Maue and Dr. Devon Burr
NAU Department of Astronomy and Planetary Science

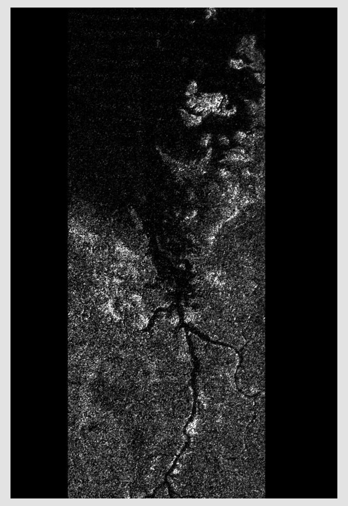
Abstract

In this ongoing research project, I have been working with data taken from several alluvial fans in Death Valley to find radar data analogous to that of the fluvial environments on Saturn's moon Titan. This project has two distinct parts, the first involves taking images from several locations in Death Valley and converting them into 3D meshes from which surface roughness can be measured, and the second involves mapping the lithology of the alluvial fans and their catchment areas. The findings from these two phases can then be compared to determine factors like composition and age that impact the roughness of fan deposits.

Background

Alluvial Fans are essentially surface deposits in the shape of cones or fans emanating downslope from a point where a stream leaves a mountain. These areas have varying-sized sediments that were carried from their catchment areas up in the mountains (Bull, 1968).

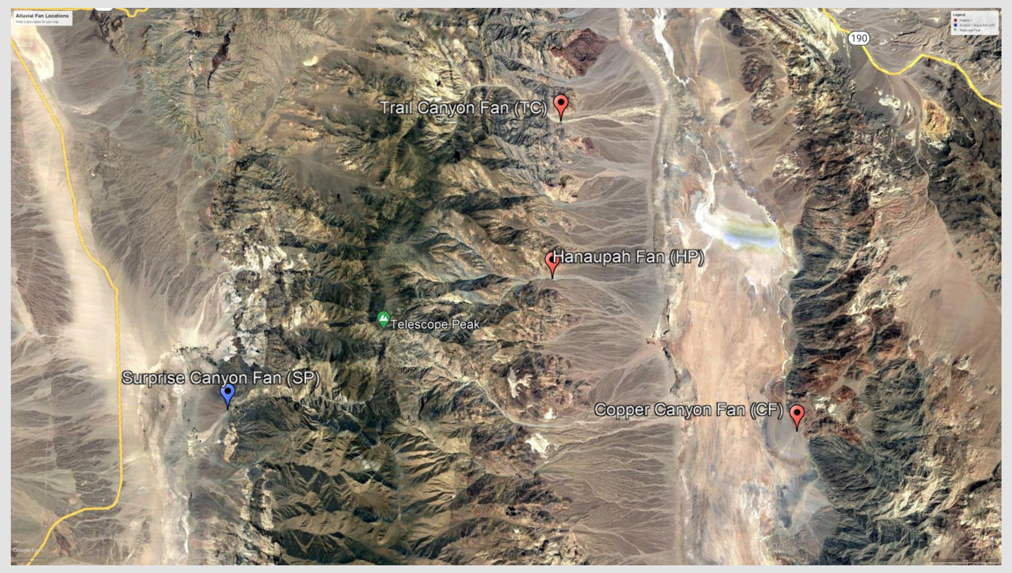
Saturn's moon Titan has fluvial environments, river-like environments, that were observed by the Cassini-Huygens probe. These areas can measure hundreds of kilometers in length, but because of the extreme cold temperatures on Titan they are formed by a liquid Methane hydrological cycle. These features present on Titan make it uniquely similar to Earth in that its precipitation and fluvial cycles are currently active (Lorenz et al, 2008).



NASA/JPL-Caltech/ASI

Location

Death Valley was chosen for this study because of the arid desert environment it provides. Low moisture and little vegetation allow for precise radar data to be taken of this area. Also, other studies have utilized Death Valley when studying the depositional processes on alluvial fans (Maue et al, 2019).



Quantifying Surface Roughness

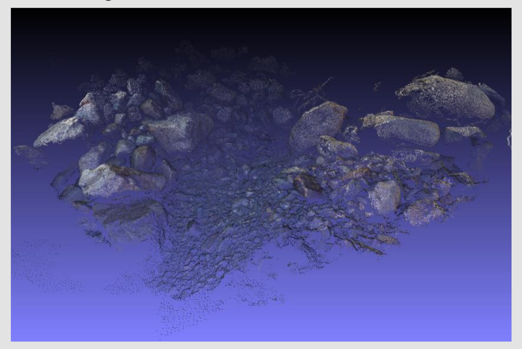
To get the roughness estimates of particular areas on the fans I used the programs Regard3D, MeshLab and MATLAB. I took raw images captured from these locations and converted them into pointclouds so that roughness could be quantified as root mean square (RMS) height.

I will present two different areas of study, each taken from Hanaupah Fan. The sample area on the left is HP07A and the sample area on the right is HP03A. I selected these two areas to show the extremes of roughness. HP07A has a high RMS while HP03A has a low RMS.

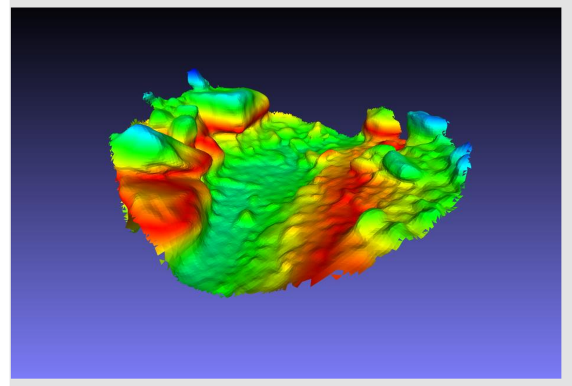
This is one of the raw images for HP07A. The surface is not smooth at all and is comprised largely of varying-sized rocks.

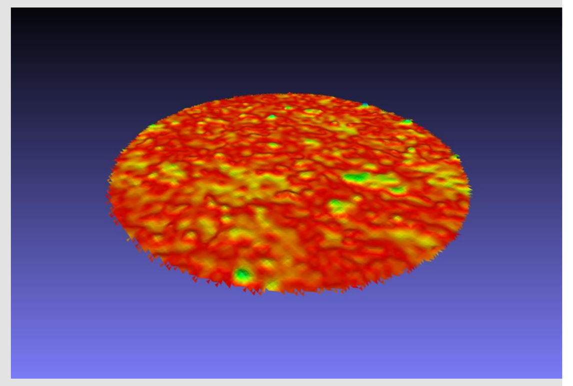
This is one of the raw images for HP03A. The surface is considerably smooth with little variation in rock size

Below are the pointclouds created from the raw images taken of the two areas. These are just points in space that will later be used to create a surface that can be analyzed.



Below are the surfaces created from the pointclouds. Each finished surface is a circular area with a radius of 1 meter. The coloration represents the distance of a point from a plane fitted to the surface. The plane functions as a 3-dimensional best fit line that measures the average height of the surface. Red areas on the surface are those right on the plane, while blues are areas farthest from the plane.



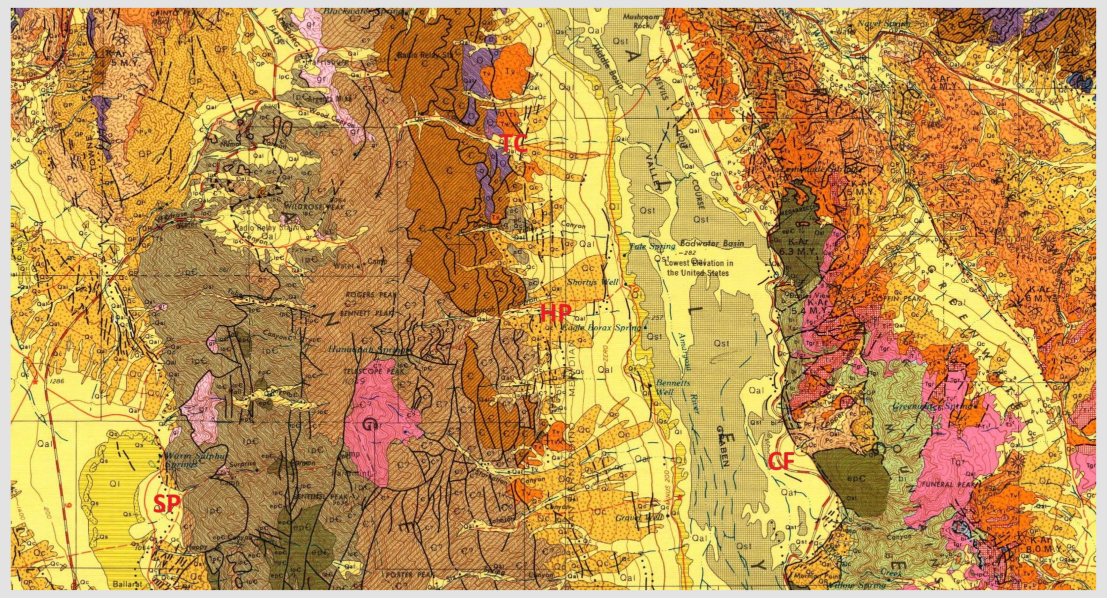


The surface HP07A has a large range of colors due to its high RMS value while the surface HP03A is almost entirely red due to most points on it being close to the plane. This is a good visual representation of its low RMS value.

Mapping Catchment Areas

In the second part of this project, I began mapping the catchment areas of the alluvial fans studied to see if there was a correlation between the composition of the catchment areas and the roughness of the fans.

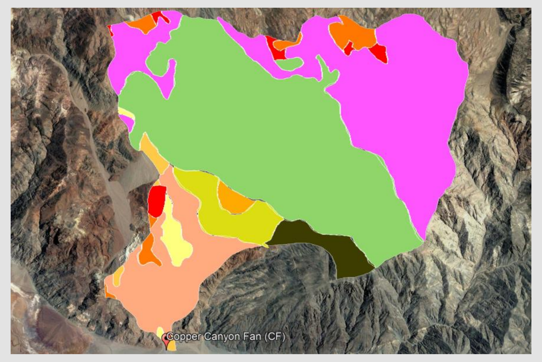
My main source for mapping the geologic units found in the catchment areas is the map created by Streitz and Stinson in 1974. This map not only provides a detailed geologic survey of all the fans in the study, but also labels and explains them in detail.



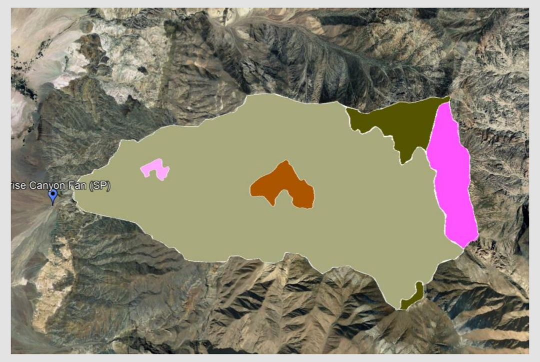
This portion of the map by Streitz and Stinson contains the four catchment areas shown below.

I then used Google Earth to map the catchment areas of each fan by drawing polygons overlaying the catchment area. I could then find the percentage of the catchment area that the individual units made up. Below are four examples of the eight fans that were studied.

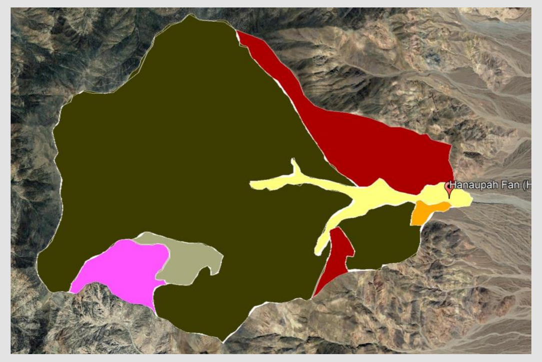
Copper Canyon Fan Catchment Area



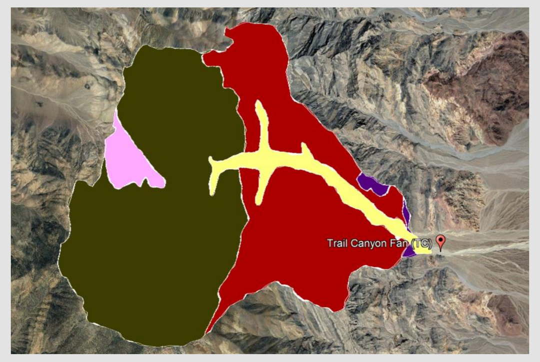
Surprise Canyon Fan Catchment Area



Hanaupah Fan Catchment Area



Trail Canyon Fan Catchment Area



Dark Green: Cambrian Precambrian Marine Sedimentary

Dark Red: Cambrian Marine

Gray: Later Precambrian Sedimentary and Metamorphic

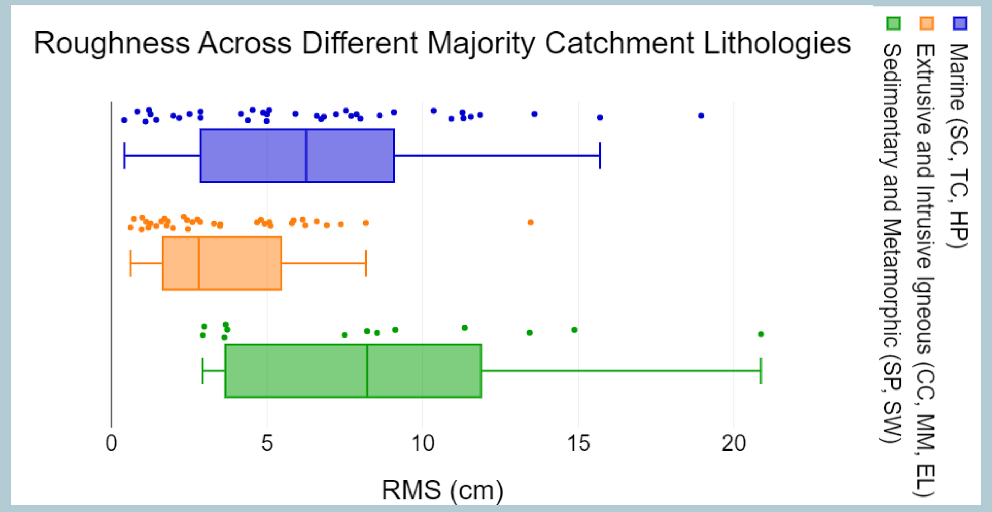
Mint: Mesozoic Intrusive Igneous

Hot Pink: Tertiary Granitic

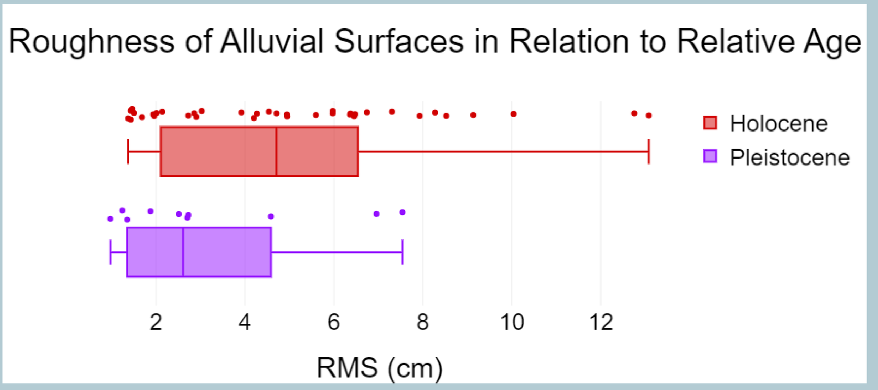
Results

By mapping the lithologies of several catchment areas, I was able to identify the type of rock that made up their majority.

Majority Marine Sedimentary	Majority Igneous	Majority Sedimentary and Metamorphic
South of Cottonwood Canyon (SC)	Copper Canyon (CC)	Surprise Canyon (SP)
Trail Canyon (TC)	East Lila (EL)	Stovepipe Wells (SW)
Hanaupah (HP)	Malpais Mesa (MM)	



When the RMS heights are plotted for each area of study it is observed that fans with igneous catchment areas have the lowest roughness; however, all three lithologies have significant overlap. This suggests that the **geologic composition is not the main determining factor of surface roughness.**



Finally, the RMS was plotted with respect to the age of deposits on the alluvial fan surfaces based on Slate et al 2009. Though there is significant overlap in the two ages, the younger Holocene deposits includes a range of deposits with a higher roughness. This difference may indicate that **deposits with longer exposure to erosion will be less rough.**

Acknowledgements

This research was supported by NASA through Solar System Workings grant NNX16AG09G. Field data was collected in Death Valley National Park according to permit #DEVA-2020-SCI-0036.

References

[1] Slate, J.L., Berry, M.E., and Menges, C.M., 2009, Surficial geologic map of the Death Valley Junction 30’ × 60’ quadrangle, California and Nevada: U.S. Geological Survey Scientific Investigations Map 3013, 1 sheet, scale 1:100,000.
[2] Streitz, R., & Stinson, M. C. (1977). Death Valley Sheet Geologic Map of California. chart, State of California Department of Conservation Division of Mines and Geology.
[3] Maue, A. D., Carnes, L. K., & Burr, D. M. 2019. GRAIN PROPERTIES FROM SYNTHETIC APERTURE RADAR: TERRESTRIAL RADAR ANALOGS FOR TITAN'S ALLUVIAL SEDIMENT. 50th Lunar and Planetary Science Conference 2019.
[5] Bull, W. B. (1968). Alluvial fans. *Journal of Geological Education*, *16*(3), 101-106.
[6] Lorenz, R. D., Lopes, R. M., Paganelli, F., Lunine, J. I., Kirk, R. L., Mitchell, K. L., ... & Cassini RADAR Team. (2008). Fluvial channels on Titan: initial Cassini RADAR observations. *Planetary and Space Science*, *56*(8), 1132-1144.