# Exploring the topography of Mount Rainier and its impact on the transport of debris to the supraglacial system

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**Abstract:** In this study I will be looking at the effects of topography within a glacier's rock-shed on the transport of debris from surrounding glacial features to the glacier surface. The glaciers targeted for this research were Emmons, Frying Pan, Nisqually, and South Tahoma Glaciers. Debris that gets transported to the glacier surface has the ability to impact and prolong the glaciers life (Pelto, 2000). It is important to understand this transport process so that we can gain a better understanding of a glaciers life span. In order to evaluate this I worked with a GIS program, ArcMap, that allowed me to create a slope and feature map. These maps allowed me to see the steepness of the topography in the rock-shed and the possible supplies of debris to the glacier surface. After this was done a scoring system was used to evaluate the overall likelihood of each glacier's rock-shed to supply debris to the glacier surface (Saroglou, 2019). Steepness showed to have a moderate impact on the transportation of sediment to the glacier surface. The size of the rock-shed also didn't show to impact the transportation of debris to the glacier surface.

**Question:** How does topography of Mount Rainier National Park impact the amount of debris transported to the supraglacial systems of Mount Rainier's glaciers?

**Hypothesis:** Glaciers in a steep topographic setting with a larger rock-shed relative to the glacier will have a larger amount of debris in the supraglacial system than glaciers with a smaller rock-shed and less steep topographic settings.

## Introduction & Background

- Mount Rainier is the tallest glacially active mountain in the state of Washington at 14,410 ft, presenting some of the steepest topography in the Cascades. (Fiske, 1963)
- Supraglacial: Is referring to the surface of a glacial system.
- There are two sources of debris that contribute to the supraglacial system which are bordering rock walls (direct), and lateral moraines (indirect). (Woerkom et al., 2019)
- Rocks present on the supraglacial system are characteristically angular indicating that the rocks were transported from a rock wall or lateral/medial moraine. (Boulton, 1978)
- Moraine: Unstratified and unsorted deposits of sediment that form through the direct action of, or contact with, glacier ice. Many different varieties (lateral/medial) are recognized on the basis of their position with respect to the glacier. (USGS)
- Rock-sheds are a way to interpret what local features and areas contribute to glacier debris cover, much like a watershed.
- Data for this research was collected using a geographic information system (GIS) which is a computer system that analyses and displays geographically referenced information. (USGS)

**Motivation:** We know that debris cover on glaciers has the ability to impact the lifespan of glaciers, because the supraglacial debris can insulate the ice from the heat during warm seasons (Pelto, 2000). By working to understand how the topography of the surrounding features affects the transportation of debris to the supraglacial system of the glaciers at Mount Rainier we can better estimate the lifespan of these glaciers.

## Study Glaciers on Mount Rainier


Figure 1: This map was constructed using Google Earth Pro to display the glaciers of interest for this study.

## Methods

- A weighted scoring system to determine the susceptibility of debris transport from the surrounding rock-shed to supraglacial system was determined to be reliant on these factors (Saroglou, 2019):
  - These factors being slope (fig. 2), glacier area/rock-shed area (㎡), debris area/glacier area (㎡), a percentage of glacier perimeter in contact with moraines (m), and points allocated for however many features are present in the glacier rock-shed (Fig. 3).
  - Points will be added up and the highest point total indicates the glacier with highest likeliness to transport debris to the glacier surface.
- ArcMap was used to create the maps presented as well as determine the values for the categories above.
  - ArcMap is a GIS program that analyzes geospatial information and allows users to create maps of the geospatial data. (ArcGIS)(Fig. 2&3)

**Slope Map**: This was the sequence of tools and processes used to create the slope map (fig. 2).

DEM → Project Raster → Re-project → Slope / Hillshade → RS Shapefiles → Merge → Clip → Classify Slopes

**Feature Map**: This shows the sequence of steps used to create the feature map (fig. 3).

Imagery → Change CSYS → Add Glacier Outlines → Draw Feature Shp. → Add Features to RS Shp.

## Results

- The slope of Nisqually, Emmons and South Tahoma Glaciers were all very similar with a peak range of 30%-37%; Frying pan Glacier showed the lowest peak slope at about 17% (fig. 2).
- Nisqually Glacier showed the largest debris cover at 2,409,276 m^2; Frying Pan showed the smallest debris cover at 91,505 m^2
- Three out of four glaciers had a bedrock feature present in its rock-shed (fig. 3).
- Nisqually and Emmons were the glaciers with the most moraine features present at four and three respectively (fig. 3).
- South Tahoma Glacier scored the highest total points and Frying Pan Glacier scored the lowest total points (table 1).

Figure 2: This map was created with a DEM where data was collected via LiDAR technology (USGS)(Sisson et. al. 2008). The intent of this figure is to display the range of slopes found on the glaciers and its surrounding rock-shed.

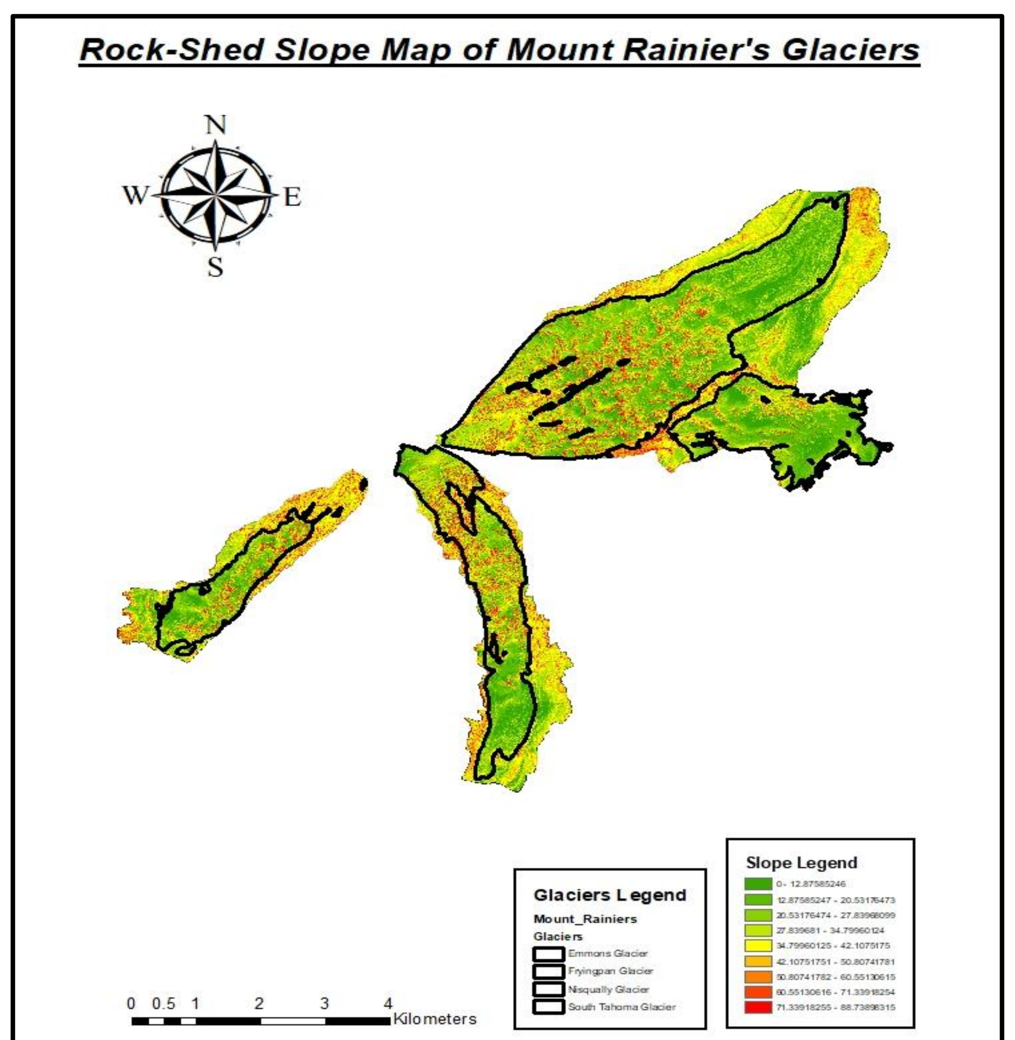
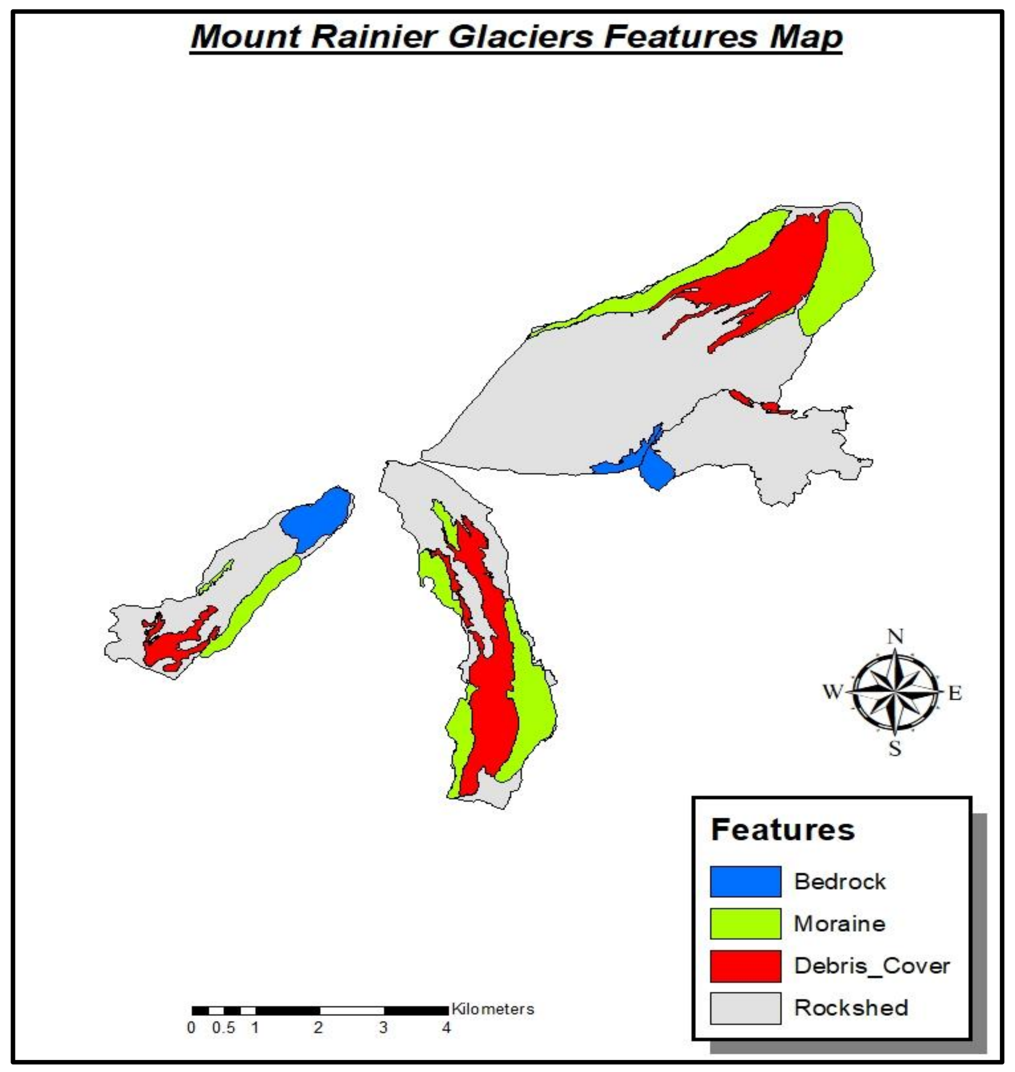



Figure 3: The slope map was created using aerial imagery of Mount Rainier National Park. Features were determined by identifying characteristics of moraines and headwalls. Imagery was provided by the digitalglobe




| | Slope (Mode) | Glacier/Rock-shed (m^2) | Debris Cover/ Glacier (m^2) | # of bedrock features | # of moraine features | % of glacier perimeter in contact with moraine (m) | Total |
|---|---|---|---|---|---|---|---|
| Emmons | 3 | 1 | 1 | 1 | 2 | 1 | 9 |
| Frying Pan | 1 | 0 | 0 | 1 | 0 | 0 | 2 |
| Nisqually | 3 | 1 | 3 | 0 | 2 | 2 | 11 |
| South Tahoma | 4 | 2 | 1 | 2 | 1 | 2 | 12 |

Table 1: This table is to show all the factors used to evaluate the transport of debris to the supraglacial system. The total points indicate the likelihood of debris transport and the higher the number the higher the transport and the lower the number the lower the transport.

## Discussion

- Glaciers without moraines have the smallest debris cover of the glaciers in this study (fig. 3).
  - Sediment isn't being supplied to the glacier easily because bedrock does not transport as readily as loose moraine sediment do.
  - Moraine features are crucial to the lifespan of a glacier because moraines are more readily able to transport debris than a bedrock feature would be able to.
- Emmons had a surprising score of 9 which placed it below Nisqually and South Tahoma (table 1).
  - As the study progressed Emmons, just from looks, looked to be the clear favorite for getting the highest score but at the end Emmons scored the 3rd lowest score.
  - The 1963 Little Tahoma Rockfall helps this strange data make a little more sense (Fiske, 1963).
  - Most of the debris is likely from the Little Tahoma Rockfall (Fiske, 1963).
  - Large bedrock collapses can provide large amounts of debris to the supraglacial system where moraine features typically can not reach (Fiske, 1963 & Woerkom et al., 2019).
    - There must be harmony between the transportation from bedrock features and moraine features to help support the glacier lifespan.
- Glaciers with large rock-sheds relative to the glacier size, did not show a larger amount of debris on the glacier surface (table 1).
  - South Tahoma has the smallest glacier size relative to its rock-shed. This would indicate that the South Tahoma Glacier is much smaller in comparison to its rock-shed.
  - South Tahoma showed the second smallest debris cover which based on my hypothesis would mean it has small rock-shed. But in fact South Tahoma had the biggest rock-shed relative to the glacier itself which should have yielded a higher debris cover.
- The steeper the topography doesn't have a significant impact on debris cover (table 1).
  - South Tahoma Scored the highest in steep topography within the rock-shed but still yields the second lowest debris cover.
  - With the steeper slopes my hypothesis would have been correct if South Tahoma had a larger debris cover but it didn't and therefore likely doesn't have a significant impact on debris transport.

## Conclusion

- Transport of debris to the glacier surface is moderately determined by the steepness of slope within its rock-shed, but there are many other factors that contribute that need to be tested further to understand how and why debris gets to the surface of glaciers.
- Moraines provide debris to the glacial margins effectively and at a steady rate whereas bedrock features supply larger amounts to areas moraines can't reach at an inconsistent rate. In order to sustain glacial life these two processes must work in a balance with one another.
- The size of a glacier's rock-shed does directly impact the amount of debris transported to the glacier surface; it is what's within the rock-shed that has the greatest impact.

## Future Work

- Evaluate glacier similar to Emmons to understand glaciers on N to NE flank of Rainier.
- Include perimeter of Glacier in contact with bedrock.
- Evaluate the impact of the glaciers basin has on the transportation of debris to the supraglacial system.

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