Comparing Supraglacial and Proglacial Debris on Emmons Glacier, Mt. Rainier, Washington

Benjamin Lungberg
Department of Geosciences

Abstract:

Emmons Glacier, which is located on the Northeast flank of Mt. Rainier, Washington has an ablation zone and proglacial area that are covered in rock debris. In this study, hand sample field analysis, data synthesis, and analysis of aerial imagery were done to determine the origin of the debris in the supraglacial and proglacial areas. Rock samples analyzed along the surface of the glacier show a majority of angular clasts suggesting an origin of wasting, likely rockfalls. Rock samples from the proglacial zone show an overall rounded characteristic, meaning that the debris went through entrainment and tractional contact with the bed, likely through a subglacial fluvial system. Evidence of a large moulin and surface crevasses back up the theory of origin for the proglacial zone by being an avenue from which debris that has fallen onto the glacier can make its way into the entrainment process and on to the terminus of the glacier. A very large and complex proglacial stream system suggests a powerful subglacial fluvial environment capable of eroding the bed. High weathering of surface debris makes it likely that the surface cover is mainly from the 1963 Little Tahoma rockfall event, whereas, the lack of weathering on proglacial debris argues that newer material must be being added to the system from more recent rock falls or bed erosion.

Background:

- Mt. Rainier has 25 major glaciers on its surface, which cover about 35 square miles (NPS, 2020).
- Of the 25 glaciers on Mt. Rainier, Emmons glacier is the biggest, about 4.3 square miles (NPS, 2020) also being the largest glacier in the continental 48 states. *See figure 1.*
- In December 1963 rock falls from Little Tahoma Peak on the east side of Mount Rainier volcano fell onto Emmons Glacier (Crandell and Fahnestock, 1965). *See figure 3.*

Motivation:

- Surface debris can greatly slow the rate of melt in glaciers (Anderson et al, 2018); if a debris supply is on going the glacier will continue to be covered and therefore maintain its protection from solar radiation, understanding transport and source of debris can say if the cover will remain.
- Understanding the differences in proglacial and supraglacial debris origination will help us to determine how debris is added to and taken away from the surface of the glacier and the scale at which it occurs.

Question: Where do supraglacial and proglacial debris originate on Emmons Glacier, Mt. Rainier, Washington?

Hypothesis: My hypothesis is that the debris in the proglacial area is from valley walls and bed erosion and has been transported through a subglacial fluvial environment, and the debris on the surface of the glacier is from rock falls from Little Tahoma Peak and the glacier basins edge.

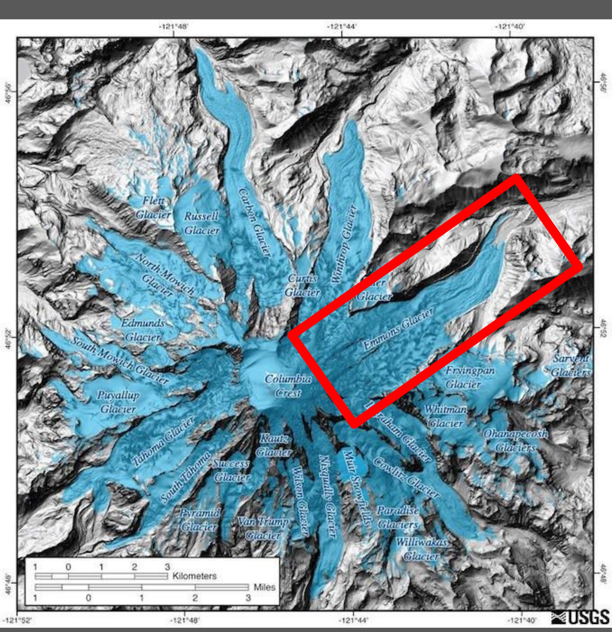

Figure 1: Map of the Mt. Rainier "Starfish" Aerial Photo (NPS, 2020)

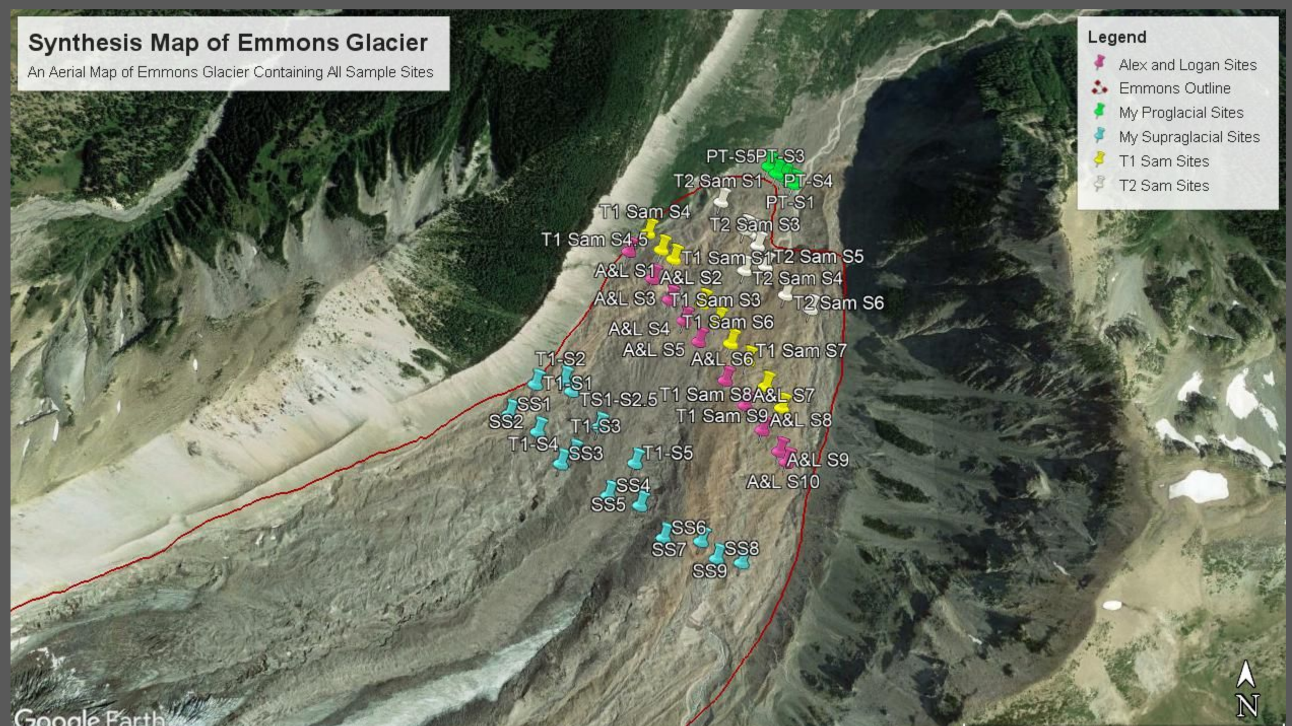

Figure 2: Field Map of Emmons Glacier with Sample Sites Marked (Generated with Google Earth, 2019, Edited 2020)

Methods:

Hand Sample Analysis: (Field)

- In the field, samples were analyzed from both the supraglacial and proglacial areas. The field samples were analyzed for size, using a C/A axial ratio (Benn and Ballantyne, 1994), color (using a Munsell Rock Color book), and rounding. The samples were taken from two GPS marked transects with recorded site locations.

Data Synthesis:

- Data from PLU Undergraduate Natural Science Summer Research (2016, 2018, 2019) was compiled to reinforce the characteristics of the supraglacial debris and the argument of its source and transport. *See figure 2.*

Satellite Image Analysis:

- Imaging from Google Earth was studied looking for holes and cracks in the surface of the glacier that could be potential avenues for transportation of debris through the body. *See figures 5 & 6.*

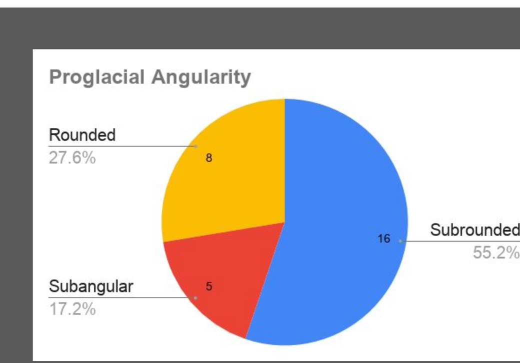

Figure 8: Angularity of all field samples analyzed from the proglacial zone of Emmons Glacier (Sample Size: 29)

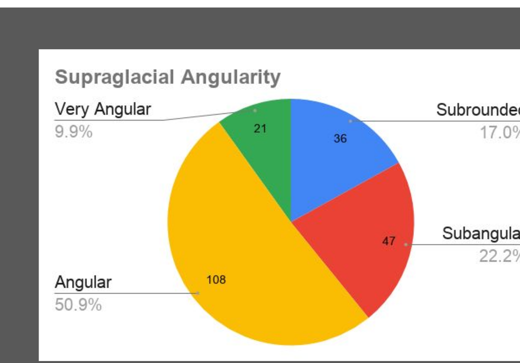

Figure 9: Angularity of all field samples analyzed from the supraglacial zone of Emmons Glacier
My data and credit to Sam Altenberger, Alex Yannello, and Logan Krehbiel (Sample Size: 212)

Figure 8: Example of a rounded clast from the proglacial zone

Figure 9: Example of an angular clast from the supraglacial zone

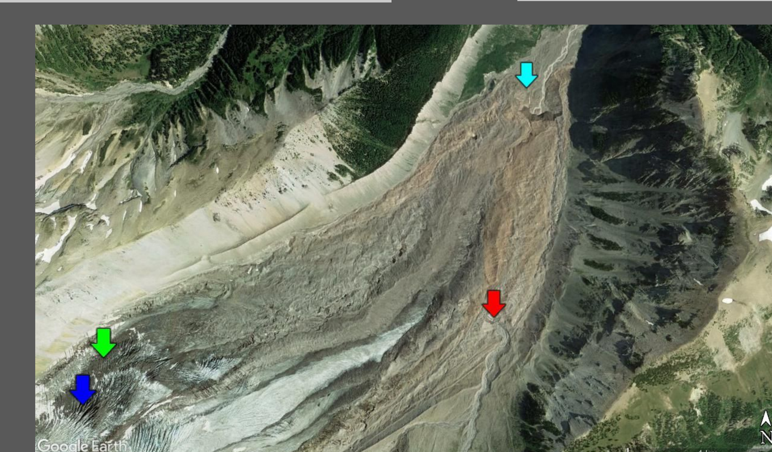

Figure 7: Emmons Glacier, locating the noted features. proglacial area with large stream environment (Teal), moulin (Red), compression cracks (Green), and extension cracks (Blue) (Generated with Google Earth, 2020)

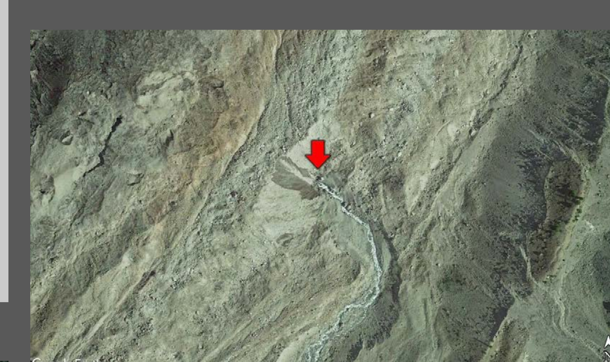

Figure 5: Satellite image of Emmons Glacier with a moulin (marked in red) on the surface (Generated with Google Earth, 2020)

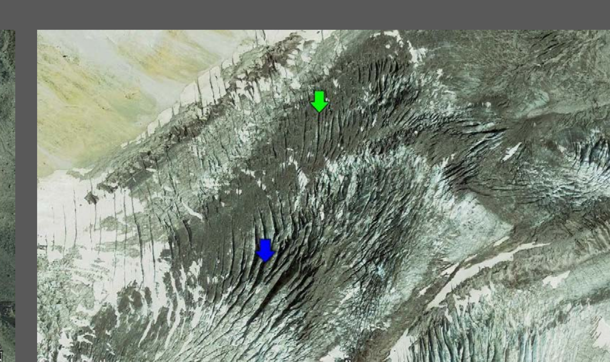

Figure 6: Satellite image of Emmons Glacier with extension (Blue) and compression (Green) cracks on the surface (Generated with Google Earth, 2020)

Figure 4: A comparison of the unweathered proglacial debris (left) and the highly weathered supraglacial debris (right)

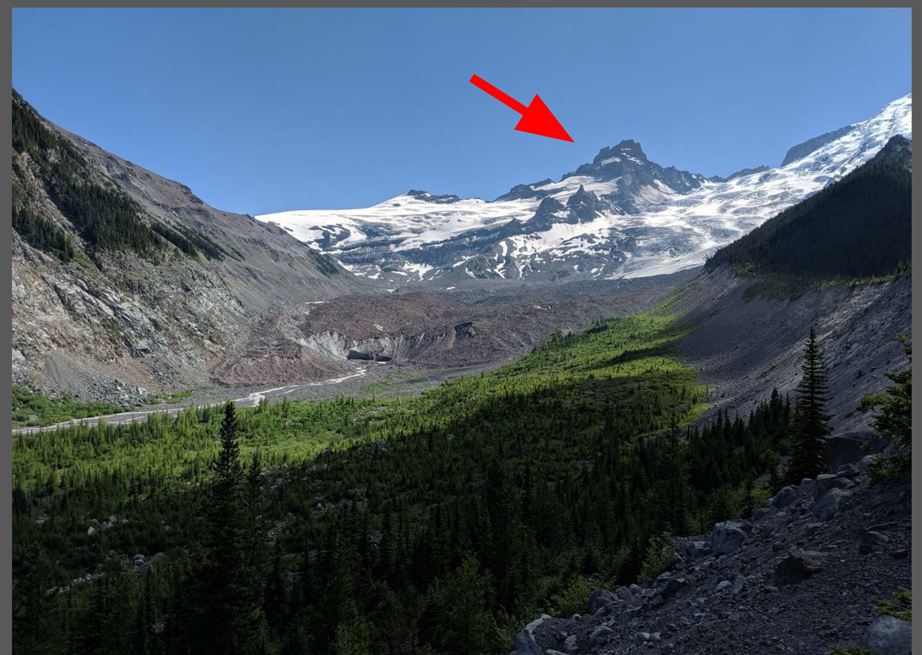

Figure 3: Little Tahoma Peak up above Emmons Glacier

Results:

- Majority minimally weathered rounded to subrounded clasts in the proglacial zone.
  - 82.8% of samples collected. *See figure 8.*
- Majority very weathered angular to subangular clasts in the supraglacial zone.
  - 73.1% of samples collected. *See figure 9.*
- Presence of high volume moulin and large field of crevasses on the surface of the glacier near valley walls. *See figures 5, 6, & 7.*
- Supraglacial debris cover had presence of red oxidation, proglacial debris had fresh clean grey surfaces.
  - Supraglacial debris was crumbly and weak (breakable in hand), proglacial debris was sturdy and strong. *See figures 4 and 10.*

Discussion:

- As speculated, clasts in the supraglacial zone likely from Little Tahoma rockfall event due to the sharp angularity and extensive weathering of the debris.
  - Debris from supraglacial surfaces is generally dominated by angular clasts (Hambrey et al., 2008).
- Debris produced above the glacier by fracturing of rock walls has a dominant coarse fraction with angular boulders (Boulton, 1978)
- Due to the rounded nature and freshness of the debris in the proglacial area, coupled with the presence of a wide spread, high volume, and complex proglacial stream system, it would stand to reason that it was transported fluvially.
  - Considering the moulin and the crevasses near the valley walls debris that is eroded off would have an avenue to be entrained and make its way to the terminus.
  - Boulders transported through the tractional zone will tend to be rounded (Boulton, 1978). *See figure 11.*
  - Debris transported by glacier is derived either supraglacially from nunataks and valley sides or from erosion of the subglacial bed (Boulton 1978).
- Debris also becomes entrained from the surfaces by falling into crevasses (Hambrey et al., 2008).
- Glacier surfaces can see contribution of debris from lateral moraines, as the glacier surface lowers the basin's edge becomes increasingly more unstable, leading to collapse (Hambrey et al., 2008).

Figure 10: A clast with a very high degree of weathering taken from the supraglacial zone of Emmons Glacier

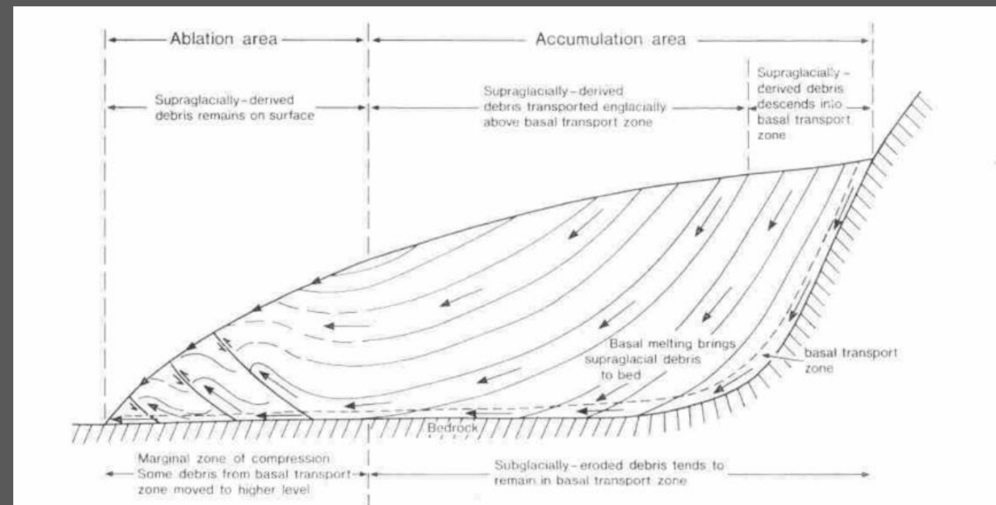

Figure 11: A diagram of travel paths for supraglacially derived debris, how it makes its way through the surface and to the basal zone, *taken from: (Boulton, 1978).*

Conclusions:

- Supraglacial debris is made up in the majority of material dumped on the surface of Emmons glacier by the 1963 Little Tahoma rockfall event.
  - With some contributions from valley walls.
- Proglacial debris consists of clasts that eroded off of valley walls and entrained through moulins and cracks.
  - This debris made its way to the terminus through the subglacial fluvial system of meltwater.
- The Little Tahoma rockfall event dropped the large blanket of debris on the surface, but the glacier continues to receive contributions from the valley walls and is sustained in this way.
  - Lack of weathering in proglacial area suggests that newer material (newer than 1963 event) is being carried through the system.
- Both the proglacial and supraglacial debris are sourced from rock falls and erosion of valley walls, the proglacial debris however, has the added step of being entrained and transported to the terminus.
- The proglacial area is also seeing debris contribution from scouring of the bed due to the erosive nature of the glacier's tractional zone and the fluvial system.

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