Control of lithological properties on erodibility in fluvial impact erosion

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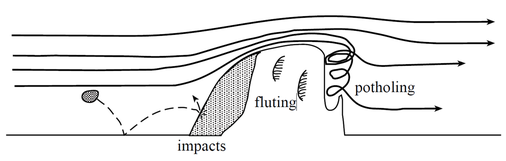
Key points

1) Combination of field (Schmidt hammer and fracture intensity) and flume measurements
2) Abrasion rate correlates with compressive strength only in lithologies with large block sizes and low fracture intensity
3) Macro-abrasion occurs in vessicular top and plucking or abrasion in massive bottom of basalt lava flows

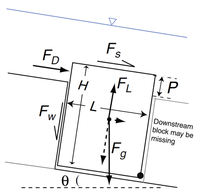
1) Introduction and research goal

Bedrock river erosion is often described by abrasion and plucking processes, e.g. for modeling and related with compressive strength and fracture spacing, respectively. We aim to review this assumption by combining field and laboratory measurements.

Abrasion process (Whipple et al., 2000)

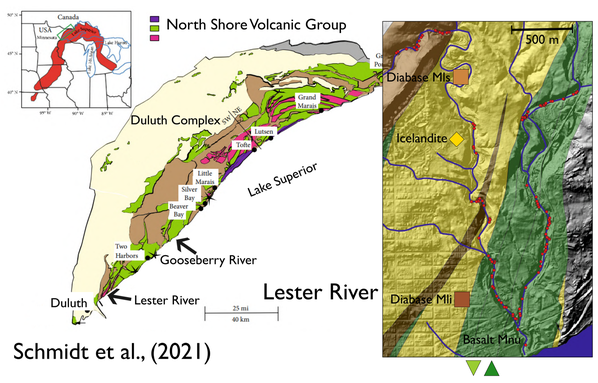


Plucking process (Lamb et al., 2015)



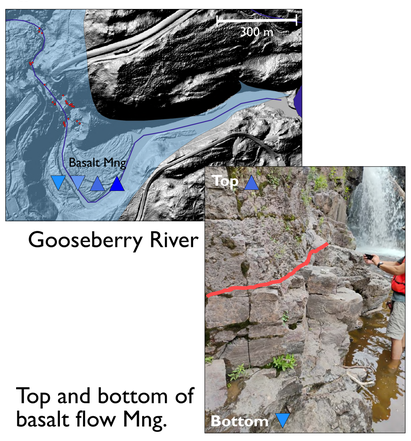
2) Sampling and sampling locations

Samples were collected in the Lake Superior basin mostly composed of volcanic and igneous lithologies (basalt, diabase, icelandite) and sandstone. In several basalt flows, the upper part of the flow contains a large concentration of amygdules. Glacial retreat caused a base-level fall of ~200 m 10.8 - 9.3 ka cal BP (Breckenridge 2013). 9 different lithologies are investigated.



Schmidt et al., (2021)

Gooseberry River

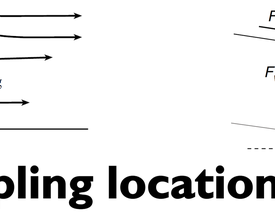


Top and bottom of basalt flow Mng.

3a) Field measurements of lithological properties

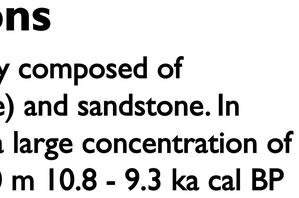
Across each lithology, several survey points were performed and include:

1) 25 Schmidt hammer measurements as a proxy for compressive strength



2) Photograph(s) for fracture intensity and block size using the image analysis software FracPaq

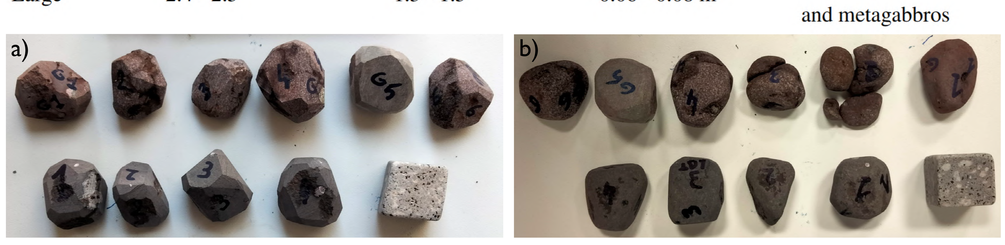
Columnar jointing and presence of amygdules in the top of the flow and massive texture in the bottom.



3b) Erosion mill experiments

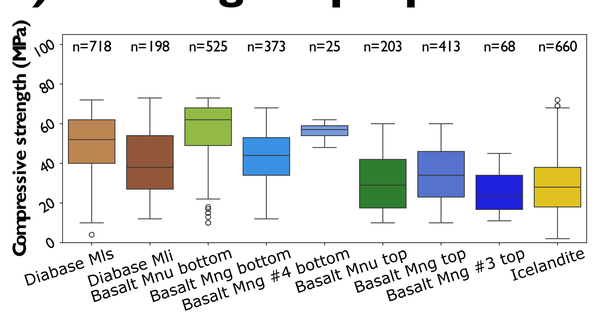
Experimental erosion mill experiments were performed in two circular flumes (Attal et al. 2006). Mass loss by abrasion (fine material) and macro-abrasion (larger particles) are quantified, plucking is difficult due to its randomness.

Flume	Water velocity (m/s)	Pebble velocity (m/s)	Pebble diameter (m)	Abrading lithology
Small	1.15	0.5 -0.55	0.02 - 0.03	0.65 kg granite
Large	2.4 - 2.5	1.3 - 1.5	0.06 - 0.08 m	53 kg orthogneiss and metagabbros

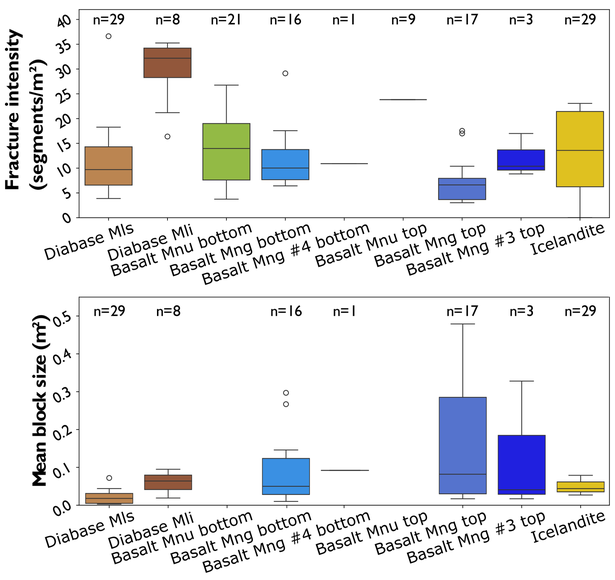


Shape of chosen pebbles a) before and b) after the experiment run. Pebbles in the top row are Gooseberry basalt from the top of a flow and pebbles in the lower row Lester basalt from the top of the flow, in the lower is a rhyolithe pebble use for reference.

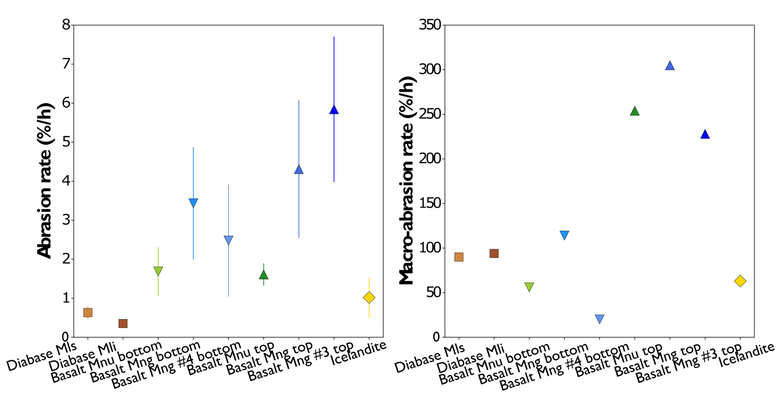
4a) Lithological properties



The top of the basalt flows has the largest block sizes, lowest fractures intensities (cooling fractures) and a lower compressive strength than the bottom. Properties of igneous lithologies vary.



4b) Abrasion and macro-abrasion rates



The flume measurements show the higher abrasion rates in the basalt lava flows than the igneous lithologies. The abrasion and macro-abrasion rates are usually higher in the top of the basalt flows than the bottom.

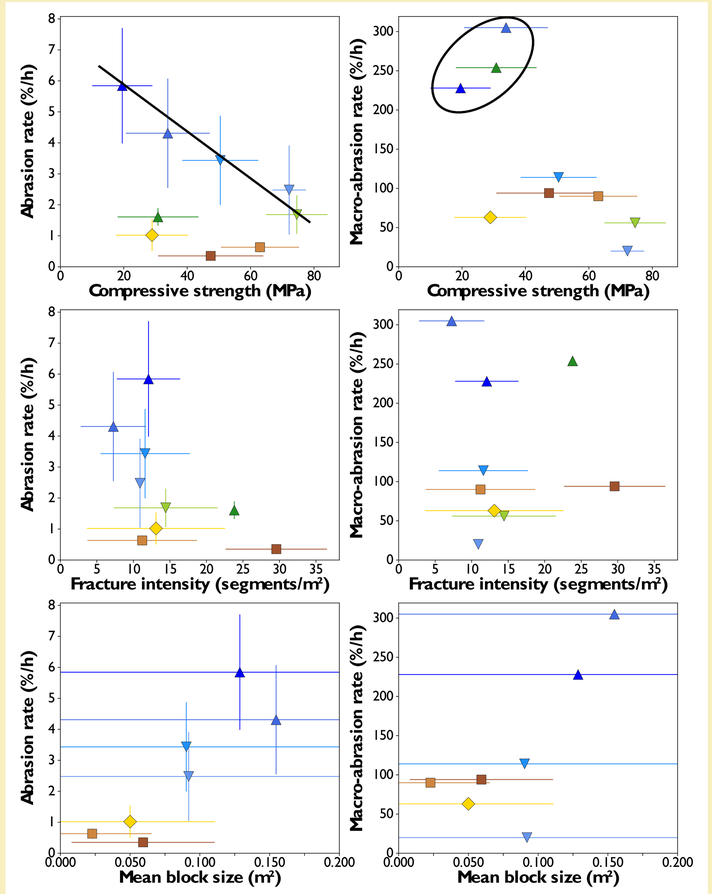
5) Discussion and perspectives

- In lithologies with low fracture intensity and large block sizes is the compressive strength a good indicator for the **abrasion rate**. However, in lithologies with high fracture intensity and small blocksizes, they seem to influence the Schmidt hammer measurements.

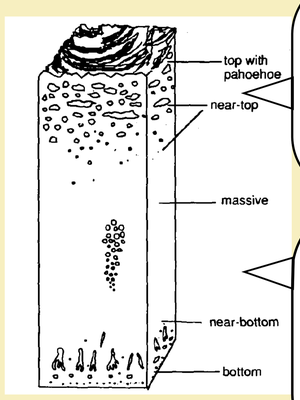
- **Macro-abrasion** occurs in size-classes between abrasion and plucking. The measured block sizes are too large and compressive strength alone cannot explain the flume results. As it is highest in the amygdaloidal top of the basalt flows, it may depend on the texture.
→ The **next step** is the analysis of thin sections to estimate the percentage of vessicles/amygdules to determine if a correlation exists.

- **Plucking** is random and difficult to measure in the flume; in field observations, it correlates with decreasing block sizes.

- One type of field or flume measeurements is not enough to fully describe erosion processes and yield information for modeling.

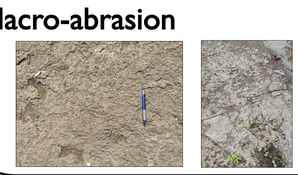


Relating erosion processes with lithological properties

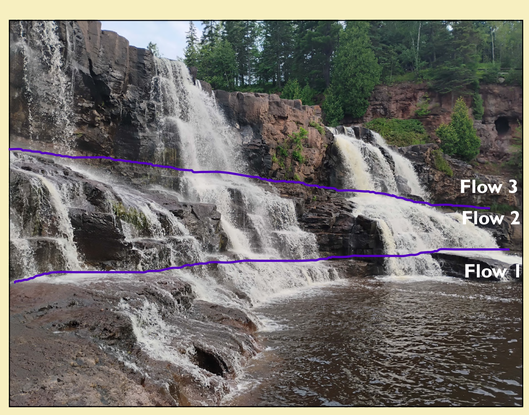


Schmidt (1993)

Amygdaloidal, vessicular top: ▲▲▲
Macro-abrasion



Massive bottom: ▼▼▼
Abrasion or plucking depending on fracture intensity and block sizes



Gooseberry Falls (Middle Falls)

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