Magnetic Rock Trail: Field Observations and Sediment Transport Processes

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The Magnetic Rock Trail in Northern Minnesota leads hikers 1.5 miles from the Gunflint Trail to a vertical spit of "Magnetic Rock" upended somewhat shockingly in an otherwise low-sloped surrounding landscape (Fig 1 & Site 2). The trail is located in the southern tongue of the Canadian Shield, and the landscape of jointed bedrock (Fig 2b) and low soil cover (Fig 2a) reflects the scraping of sediments by south-moving ice sheets during Pleistocene glaciation (1). On October 16, 2020, I hiked this trail stopping at the six tagged locations in Fig 1 to observe landscape qualities and sediment processes.

The trail traversed between coniferous forest and flat bedrock outcrops covered with angular fragments of basalt-like rocks that appeared to have broken off from the bedrock (e.g. Site 5: pine forest in background, Figs 1 & 6 demonstrate bedrock quality and fracturing). Bordering on either side of the trail were swamp-filled valleys. The south side was more visible from the path and showed a series of terraces up the hillslope (shown in Site 3: Fig 5 & Site 4: Fig 5).

Overall, many of the sediment transport processes observed appeared to be working on slow timescales. Most sites suggested that freeze/thaw and heave was likely a contributor to fracturing of rock and rockfall in locations with steep adjacent slopes (e.g. Site 2: Fig 1, Site 3: Fig 2&3, Site 5: Fig 6). Vegetation and root growth also appeared to be working to widen cracks and interstices leading to possibly immediate transport into a small stream (Site 5: Fig 5) or contributing to weathering on bedrock surfaces (Site 5: Fig 4, Site 3: Fig 4). Tree throw was also likely a prominent mobilizer of sediment—there were a particularly large number of fallen trees due to previous wildfires (est. ~10 years prior) on portions of the trail (Site 3 & Site 4). There was additionally evidence that mammals contributed to sediment transport in this region: a small mole scampered into a nook near Site 3, and a beaver had claimed a home in the marsh at the output of the bedrock stream in Site 6. Beavers are likely significant contributors to landscape development in this region—there are often multiple lodges in regional swamps. The two most rapid sediment transport processes observed in this landscape were likely rockfall off the sides of Magnetic Rock (Site 2) and cobble transport during spring flows on the small bedrock stream (Site 6).

There was a notable limitation to transport across all sites: a lack of steep gradients. While there were plenty of weathered sediments ready to be mobilized at most sites, the region appeared to lack steep enough slopes to move them anywhere. Despite having substantial precipitation and water volumes, streams in this region rapidly discharge into static water such as the swamp in Site 6 which function as sediment traps. I hypothesize that this lack of transport has led to the dichotomy of this landscape's surface composition of dominantly decomposed organic material and bedrock as shown in Fig 2a.

I expect that some of the observed transport processes would be different during the deep winter, spring, and summer. In springtime, I expect the stream in Site 6, would have enough energy to mobilize the angular cobbles at the bed (Fig 1) and would rise to cover the eroded bedrock in Fig 2. There were obvious signs of frost expanding out of the soil on my trip (Site 1: Fig 5), which would not be present during warmer months. During these months, I expect mammal activity would peak.

Ultimately, I suspect this landscape still reflects glacial erosion as the most powerful sediment transport and landscape shaping process. I wonder if we won't see significant re-shaping of this landscape until the next glacial period…if there is one.

References:

1. Bastedo, J., James-Abra, E., 2006, *Canadian Shield*, The Canadian Encyclopedia

Figures:

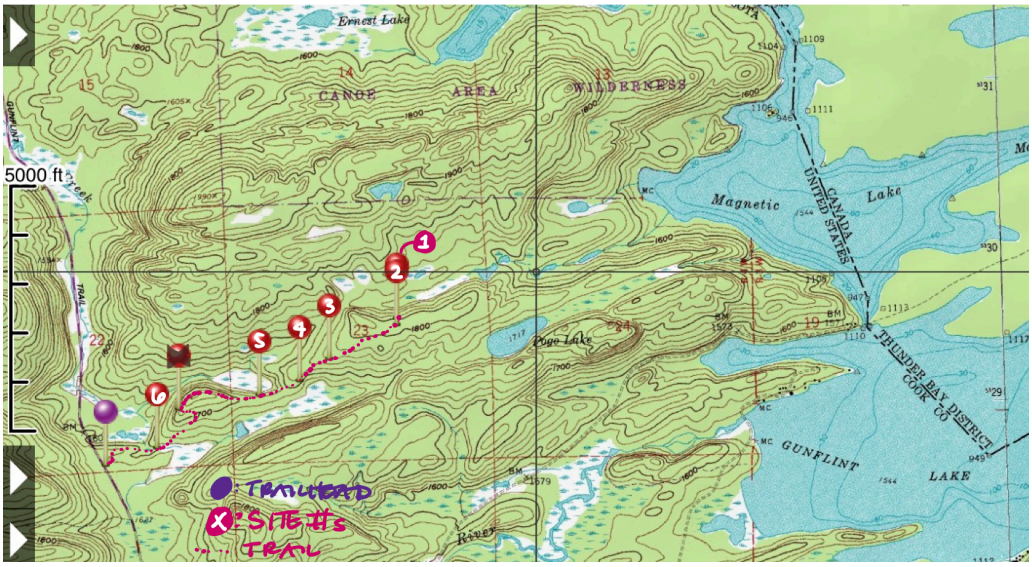


Fig 1. Magnetic Rock Trail map where field observations were taken. Sites are marked with pins and numbers correspond to site notes on the following pages

a) Rock and soil composition often showed a dichotomy between fine-grained, organic soil interspersed with bedrock outcrops. Very little gravel, sand, or other intermediate grain sizes were present

b) Example of bedrock "flats" that occurred across the length of the trail. These were often highly fractured at nearly right angles and often had chunks broken off the sides or sitting on top

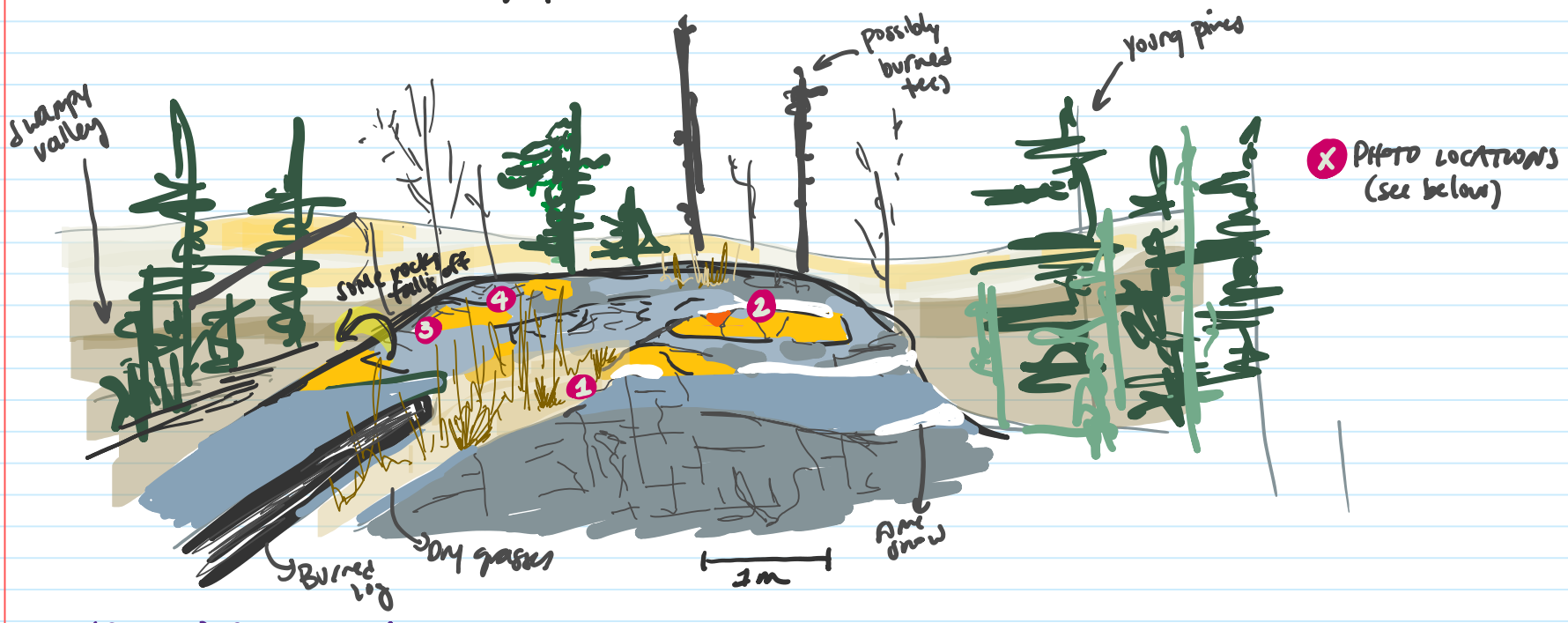
Fig 2. Representative soil and rock types observed across trail.

Field Site 1: BEDROCK OUTCROP

October 16, 2020 3:30 WEATHER: overcast, chilly, 29° F, some snow cover ~3cm deep patches

SITE DESCRIPTION

- Bedrock outcrop facing NE, overlooking swampy valley.
- Steep drop off / cliffs at edge. Some young pine trees & poplars – region appears to have burned in the past, as there are some partially blackened downed trees and dead, stripped "skeleton-like" trees still standing.
- Valley slopes down-gradient to the NE, but bedrock is angled slightly to the opposite direction (SW) and seems to be at the peak of the local topography.



SOIL/ROCK DESCRIPTION:

- Rock is very fractured, • possibly basalt; multi-colored with orange hues and in some places has a very "spotted" quality. Many fractures are at near-right angles and in places where fractures are concentrated, there are often small flakes of rock that are thin and angular. These range from the size of a dime to the diameter of a softball. Vegetation (grasses and small woody plants) grow in larger fractures. Soil present is often covered in pine needles and appears to be comprised of decaying organic matter.

PHOTO OF HIGH DENSITY OF FRACTURES WITH SMALL FLAKES OF ROCKS

SPOTTED MULTI-COLORED ROCK WITH LICHENS.

RED-COLORED ROCKS - COLOR often CHANGES SHADE AT FRACTURES. I WONDER IF THIS SUGGESTS EXPOSURE IS OXIDIZING ROCKS AS THEY BREAK OFF

SPOTTING ON ROCK SLAB - INTERESTING bumps of discoloration

SEDIMENT TRANSPORT PROCESSES

- The weathered rock flakes on top of the bedrock are quite loose: could almost be wind-transported → not much slope for sliding down
- Biological processes: lichens + plants growing on surface likely break up rock + facilitate movement – also trees growing on side of bedrock
- Tree throw: some downed trees (see burned tree in L corner of fig.) rocks + soil present in root wad
- some rocks broken off edge of outcrop – sitting at bottom of ~16 ft high cliff
- standing water in pockets on rock: perhaps this is able to convey small rocks down rock
- Frost/heave: creep of small sediment flakes + fractures (see 1) is likely accelerated by frost/heave. If they are near patches of soil, perhaps this heave can actually force them to move.
  - Frost just down the trail for this site demonstrates how mobile small sediments can be, as water in small cracks (subject to frost formation) freezes and forces its way out (see 5)

Rockfall: the ~3m drop at the edge of the outcrop shows a littering of rocks below that appear to have fallen from the top and sides of the outcrop
- rocks are likely pushed to the edge / fractured by other processes such as frost heave and perhaps fall during spring meltout

Field Site 2: MAGNETIC ROCK

Oct 16, 2020 4pm 0pm

(see photo 1)
The rock is magnetic! Someone left some unlike magnetic strips spelling "Hi" that stick right to the face of the rock! High iron content?? (also red streaks in rock)

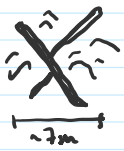
SITE DESCRIPTION & ROCK DESCRIPTION

· Vertically oriented "sharp" looking mass of rock jutting out of relatively flat surrounding area. Surrounding area forested by young pine and poplar trees. Rock appears to be embedded in fairly fine "mud like" soil

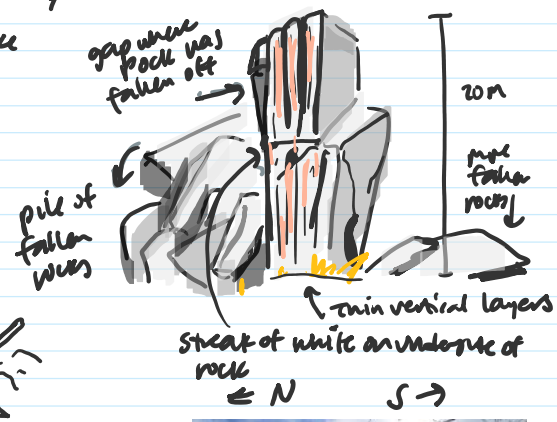
· Rock appears to be layers of pancake-like flakes sandwiched together – these are falling off both N and S faces and lay in a pile on either side

· Slight N→S downgradient slope results in a pile that is taller on this side

· V shaped fractures in South side of rock with upward facing "scales" on the surface (see 3)



· Vertical layers are multi-colored and under ledge on N side of rock there is a large white streak – possibly water percolates through top part of rock, collects minerals – these then precipitate out on lower surface (see photo 2)

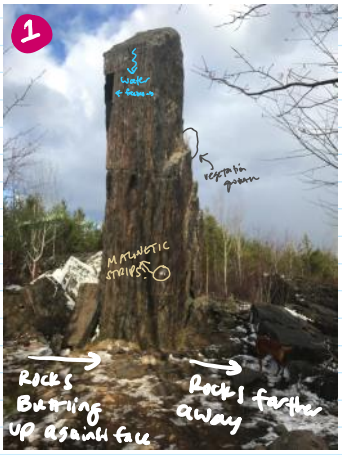


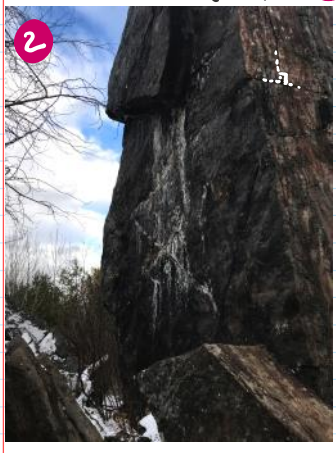
SEDIMENT TRANSPORT PROCESSES

· Gravity: helps pull flakes of rock from vertical slab (rock fall)

· Freeze-thaw: I expect this is prominent in facilitating the loss of rock from the vertical mass → water can collect in vertical cracks & then expands – combined with gravity, this could cause flakes to fall. (see photo 1)

· Soil Creep (?): only subtle slope, however the fallen flakes upslope of the rock (N-side) are more jammed up against the face of the rock while the fallen flakes on the downslope side of the rock (S-side) have moved away (see photo 1). Perhaps this suggests some slow movement?





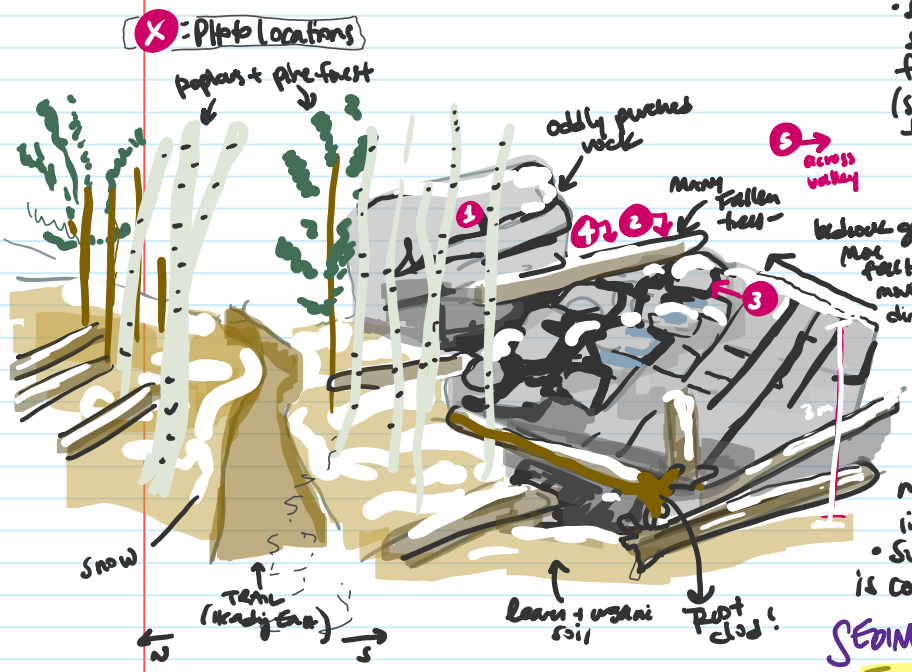
· Biologic processes: plants growing in cracks in rock face (see photo 1) also facilitates rock fall and roots extending under fallen rock may help facilitate transport down the subtle slope from N→S

· Glacial processes: I expect this rock was upended during last glaciation

NOTE: actual rock fall is going to be VERY fast compared to the rest of the transport processes → likely the fastest process in the region, although I doubt it travel very far

Field Site 3

Oct 16, 4:40pm, (max snow cover)



SITE DESCRIPTION

~3m tall cliff

- several bedrock outcrops jut out from shallow soil cover on S. side of trail top of rock in foreground is slightly higher elevation (somewhat of a cliff). The N side of the trail heads up a gentle slope – the S. side of the trail looks out over a marshy valley where, on the opposing hillslope, several "benches" of bedrock bands are exposed at different levels. (see photo 5)
- The rock is dark + likely igneous
- Fractures are more prominent nearest to the top & faces, rock is more intact "deeper" in towards soil. Many trees fallen around rockpile. Young pine + aspen forest. Fractures in rock are very angular
- Surrounding soil seems organic-based and is covered with fallen poplar leaves.

SEDIMENT TRANSPORT PROCESSES:

Freeze + thaw orientation of fractures vertical to ground plane means water can easily percolate in, freeze and break up rock (see photo 2).

Gravity facilitated Rockfall: loose rock appears to be tumbling down the face of the closest rock outcropping in drawn diagram. Drawn from above in photo 3

Root + Moss Growth: trees rooted on top of nearest rock pile in drawn diagram are often directly connected to fracture (e.g.) aspen growing out of crack)

Moss in photo 4 shows how plants growing on rock can retain water and generate cracks

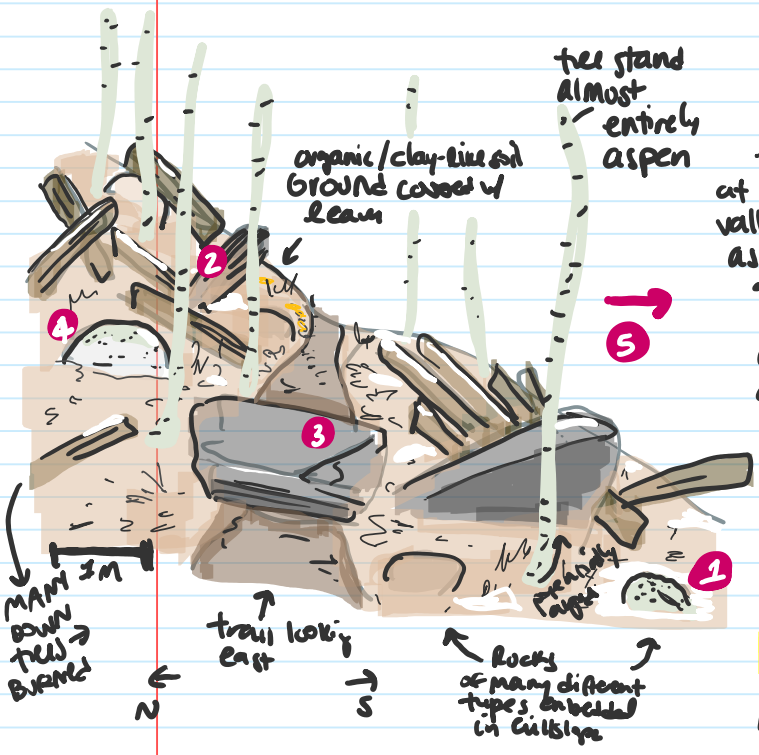
Small moles, burrowing mammals

- a small mole ran across the trail near this site and darted under a rock suggesting burrowing mammals may be active in this region

Glacial Processes

The terraced levels shown in photo 5 taken across the valley suggest glacial or glacio-fluvial processes may have carved the valley to the South, and deposited rich sediments that now make up the marsh.

Field Site 4



SITE DESCRIPTION

- "steeper" gradient hillslope, sloping down from N→S the slope extends upslope roughly 30m where it plateaus at a peak to the North. To the South, the slope ends in a valley, with the same terrace & facing hill side evident as in SITE 3. (see photo 5).
- Many different rocks are embedded in clay-like soil mixed with organic debris (leaves, twigs). Rocks are smaller, smoother and are oriented at many different angles (see photo 2 vs 1) fine rocks appear to be granitic, which is different than other sites. Many appear to be basalt - sometimes in thin layers (see 2). Burned logs indicate fire history. Tree stand dominated by poplar.

SEDIMENT TRANSPORT

Frost/heave: some aspen trunks appear to be ever so slightly curved downhill, perhaps this indicates downward, "creep-like" motion facilitated by freeze + thaw.

Tree throw Numerous (~20+) trees have fallen primarily down hillslope. (Some appear to have broken off - perhaps just burned through) leaving empty pockets upslope (+ FIRE) → possibly created thermal stresses in rocks which fractured + flaked, perhaps photo 4 is an example of this (small flake in socket of granite rock

facilitated tree throw

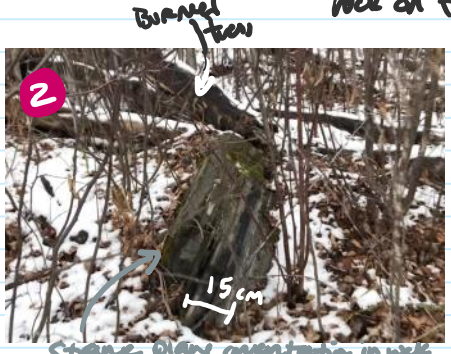
→ also likely created conditions for rain splash + runoff while landscape was still burned and unstable

Glacial Activity: Again, valley in POP 5 shows evidence of glacial activity carving out multiple terraces.

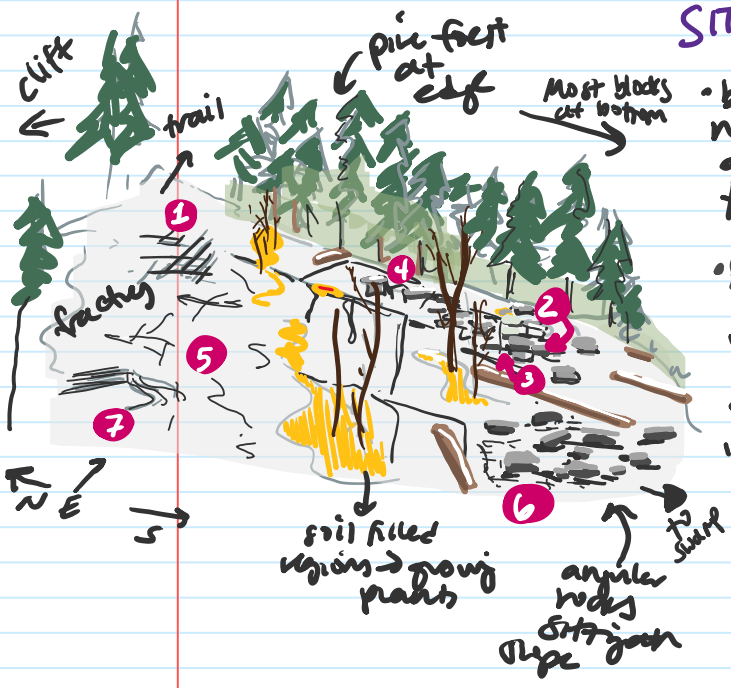
- Also, photo 3: such a prominent chunking of rock on flat ground may have been created by glacial activity

- Mammals likely facilitating sediment transport

BEAVERS in valley - "capturing sediment"



Field Site 5



SITE DESCRIPTION

- bedrock plane, at slight slope from N (upslope) to S.
- bedrock extensively fractured with many joints at nearly right angles (see photo 1)
- Crumbly, loose pieces of the same rock sit on top of the bedrock, often shedding angular shards of rock (see photo 6)
- Pine forest skirting edge of bedrock region – some soil; needles have filled fractures, sending veins of vegetation growth across bedrock plane.
- Lichens have filled cracks in rock (photo 4)
- Some of the bedrock has red veins in it spider-webbing in directions completely independent of fractures (photo 5)

SEDIMENT TRANSPORT PROCESSES:

Water/overland flow erosion: some of the bedrock regions appear to have some "scour" as you would find in a bedrock stream (see 7). I also wonder whether some of the smaller pieces (see 3) couldn't be "lubricated" to slide down the bedrock during a large storm.

Frost/heave + vegetation

- vegetation appears to break up the rocks in the regions where grasses are – I wonder if these soil "veins" provide a region for small pieces to collect and then slowly be worked downslope as the moisture rich vegetation heaves during freeze/thaw. (see 3 & 2)

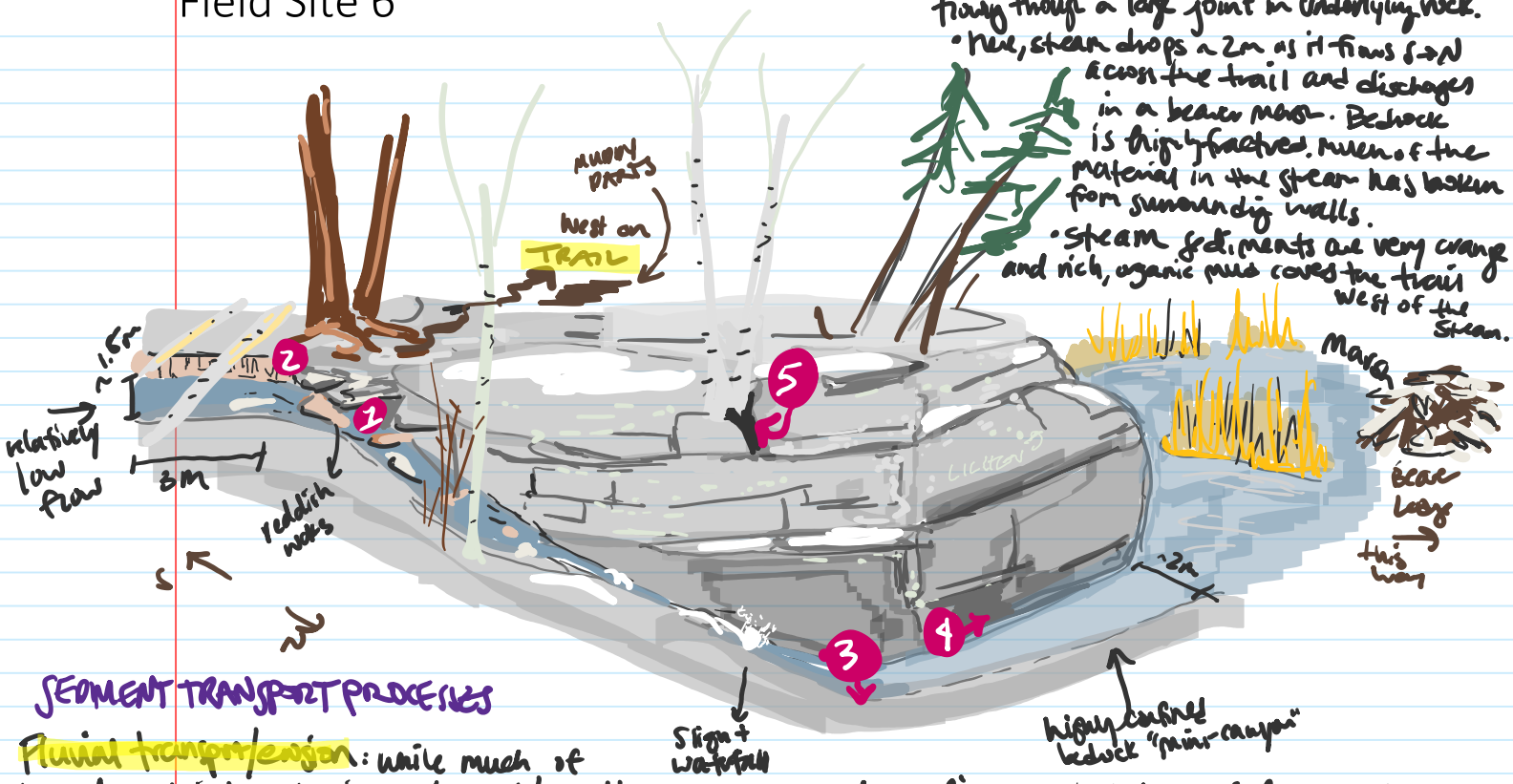
Dry sliding/rolling? thermal cracking in one of the larger chunks (fire induced or winter) could tip a piece to suddenly fall off and tumble downslope – the pieces do appear to be working their way down. However, there is no apparent "mother piece" shedding rocks upslope – It's possible these "floating" rocks are still breaking up from where they were left during ice-sheet deglaciation

Transport limited! see 2

Field Site 6

SITE DESCRIPTION

- Small ~1.5m wide bedrock stream flowing through a large joint in underlying rock.
- Here, stream drops ~2m as it flows S→N across the trail and discharges in a beaver marsh. Bedrock is highly fractured. Much of the material in the stream has broken from surrounding walls.
- Stream sediments are very orange and rich, organic muck covers the trail west of the stream.



SEDIMENT TRANSPORT PROCESSES

Fluvial transport/erosion: While much of the sediment in the river is angular and lacks the normal rounded quality of alluvial material, some clasts are likely transported in high flows, and the fine mud in the river now, is likely able to be transported in these low flows. (see 1) Also, in high flows, there is likely enough sed transported in channel to erode the side wall shown in photo 2, where the orange, fine part of the rock is more angular and looks like it's been broken up.

Frost/Heave → Rockfall: Some of the channel sidewalls have clasts that are partially slumped into the water or have fully fallen in. Where they can subsequently be eroded by the small stream. This process is likely expedited by frost heave expanding existing cracks in the bedrock on the side walls. (see 3) Additionally **Vegetation/Rooting** appears to facilitate this as in photo 5 where a large crack coincides with the base of a birch tree. The 2 large trees near the trail in the drawn figure, have roots that stretch across the trail and appear to be dislodging rocks from the wall into the stream.

Mammals (BEAVERS!) A beaver lodge to the north side of the marsh indicates sediment activity instigated by mammals including: moving of mud to create dams and lodges and creating sediment sinks by slowing flows and causing transported particles to fall out