Road Cuts in the Flint Hills: An Overview of Ecological Health and Structural Integrity

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Abstract

Road cut are a frequent sight around the Flint Hills. A poorly cut or maintained road cut can be hazardous and affect the civilians near them. The goal of this project was to determine what properties affect the deterioration of the road cuts over time. Vegetation, animals, and rock type were all studied as potential factors. Vegetation was predominantly *Juniperus virginiana, Populus deltoides, Rhus glabra,* and *Festuca arundinacea*. More birds were found on the sides with more trees, yet more bugs were found on the side with less trees. Rock type were shale and limestone. The shale was more eroded than the limestone and had slopes between 30°-55°. Shale's main hazard is if it would get on the road, and cause vehicles to lose traction. However, limestone can be more hazardous when it breaks off, due to it being heavier and larger. Schmidt Hammer values relating to rock hardness were fairly consistent over most of the limestone layers besides those layers containing chert. Those layers that included chert had higher R values than the layers without chert.

Introduction

In the Flint Hills, the construction of road cuts is nearly inevitable. These road cuts expose the bedrock that sits below the tallgrass prairie. These road cuts are layers of shale and limestone, which are susceptible to erosion. As a result, it is necessary to find the best practice for location and construction of road cuts to reduce erosion. This study is an attempt to provide introductory research and direction to future studies to answer the question of which environmental factors play a significant role in the erosion of road cuts in the Flint Hills.

There is currently much research covering the impact that vegetation has on slopes. In general, the best practice to decrease runoff and erosion is to increase the vegetation cover on the slope. The vegetation, especially when growing in soil and shale, reduces erosion by slowing the speed of water across the surface and increasing the ground's ability to hold that water (Halim & Normaniza, 2015). However, with stronger rock structures, the roots can have a negative impact on the structural integrity of the rocks, increasing the size of fractures. Larger fractures increases the chances of debris and makes road conditions more hazardous. Some have created successful mitigation and vegetation techniques but that takes money and time (Curtis et al., 2007; Paschke et al., 2000). Vegetation regrows naturally along road cuts in natural succession stages (Wenjun et al., 2008). The Flint Hills road cuts are mostly alternating layers of limestone and shale. Since these two rock types have contrasting rock strengths, slope movement is greatest at the boundary layers between the two types (Cevik et al. 2005). Water can also have a negative effect on rock strength (Avsar et al., 2014). Rock layers, and particularly shale is susceptible to erosion in areas with a significant amount of water drainage and precipitation (Maduka et al., 2017; Cevik et al. 2005). While the Flint Hills is not at high risk for landslides, that does not mean we should let the road cuts degrade without notice.

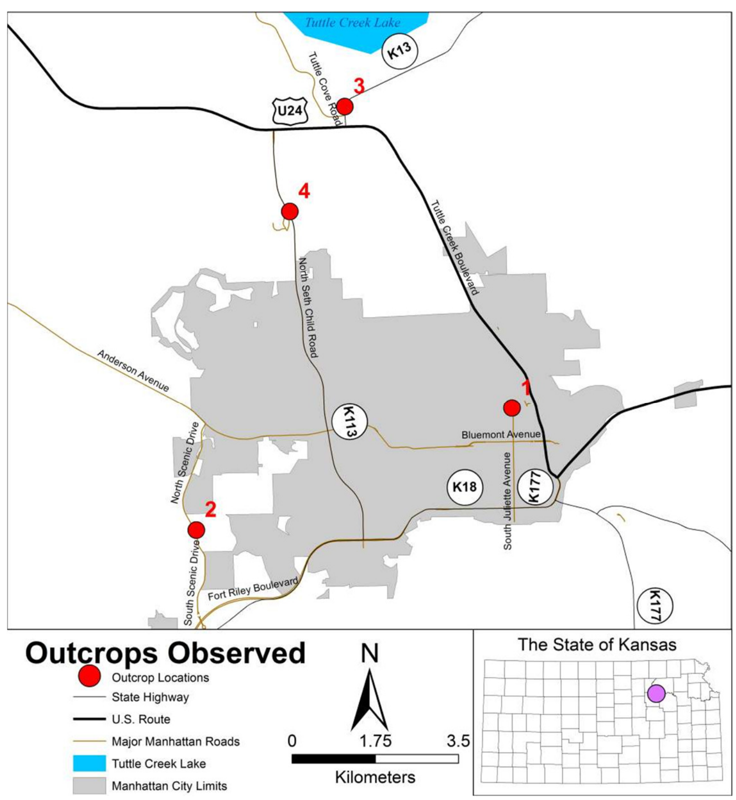
The environmental factors that this study is interested in are aspect and slope. Therefore, our guiding question is "how does aspect and slope affect the ecological health and erosion intensity for road cuts in the Flint Hills?". This study, while not attempting to definitively answer these questions, seeks to provide an introductory assessment of these factors in the Flint Hills and provide guidance for future studies on this topic. In order to answer these questions, we will use a variety of in field measurements and sampling techniques including geometric measurements taken by laser, rock hardness, visual assessment of erosion intensity and features, and animal and vegetation surveys.

The purpose of this study is to conclude what factors affect the road cuts around Manhattan, Kansas. There has not been a study in this location, and there has not been enough similar studies. Road crops can be affected by a multitude of different factors: wildlife, vegetation, age, rock type, precipitation, water drainage, height, climate of the region, etc. This paper can be used around the rest of the Flint Hills, suggesting observations techniques for these specific outcrops, and eventually ways to maintain them better.

We have two hypotheses:

Aspect is the most important factor determining ecological health and erosion intensity of road cuts.

Ecological health diminishes erosion intensity and vice versa.



Methods

Site Selection

Google Earth was used to scout and mark the locations of the outcrops on the map. Preferred locations were within 10 minutes of the K-State campus, had lower amounts of traffic, and had paired road cuts. Four locations met these criteria and were selected. GIS was used to create a map of locations:

1. Juliette Street
2. Scenic Drive
3. Tuttle Creek Dam (paired)
4. Seth Child (paired)

Vegetation Surveying

The vegetation was identified one road cut side at a time. Starting at one end of the road cut and moving to the other, the trees and shrubs were identified first using a dichotomous key. Once at the end, went back and focused on the grasses and forbs. The method for visually scanning the area for new vegetation was to walk parallel to the length of the cut and look from the very edge of the road all the way to the top of the cut. Once walking the full length of the cut twice (down and back), the relative abundance of each plant was recorded as one of the following, from least to most: few, several, many, dominant. The process was then repeated for the other side of the road cut. The overall location of plants both on the slope and relative abundance between the two slopes were noted.

Wildlife Observation Techniques

Animal observations was done by walking along the edge of the road cut making observations of animal presence and evidence of animal activity (scat, nests, etc.) Observations of animal presence included visual sightings, and sounds (calls, chirps, etc.) All observations were recorded. Data was analyzed by animal type (number of different species) and animal density (number of animals, regardless of species).

Structural Integrity Methods

A laser rangefinder determined vertical distance and horizontal distance of the rocks layers. The horizontal distance measured the thickness of the layer. Field observations were used to find grain size. Software SedLog 3.1 created stratigraphic columns of each road cut, with measurements of thickness of the layer and grain size. Vertical distance was used to calculate slope of the eroded shale.

Rock Schmidt Hammer calculated rock hardness by measuring the elastic properties of the rock. Ten impacts were used to calculate a mean value for the ASTM D 5873 method (Rock Schmidt. 2016. *Operating Instructions.* Proceq). For the Weathering Grade Method (WG), only two impacts were required for calculation, though each impact had to be in the same spot (Rock Schmidt. 2016. *Operating Instructions.* Proceq). Test locations could only be possible for intact rocks. Limestone was the only rock type measured with the Rock Schmidt Hammer. The shale bedding were layered and to fractionated to get any accurate readings in the field. Lower rebound values indicate a weaker rocks. A strong rock would have a high value.

Erosion Measurements

In the given timeframe of this project, general observation techniques were taken to get a general feel of the scale of erosion at each site and as well as to compare to each other. During the physical interactions at each site, several factors were observed to use at each site as a comparison. Comparable factors from each site could then be used to find some similarities and differences between outcrops. Each site was documented with a series of pictures for reference. The main observations for this procedure are limestone undercutting, general composition of rock and sediment, sediment and limestone deposits at the base and roadside, obvious moisture variants, vegetation differences, rooting structures, rill erosion, and shale gradients.

Results

Vegetation

	Juliette St.	Scenic Dr.	Tuttle Creek Dam Rd.		Seth Childs Rd.	
	South Facing	West Facing	East Facing	West Facing	East Facing	West Facing
Juniperus virginiana	Dominant	Several	Many	Many	Dominant	Dominant
Populus deltoides		Few	Many	Many	Several	Several
Juglans nigra			Few			
Cercis canadensis			Several	Few		
Lonicera tatarica	Few	Few				
Rhus glabra		Many	Many	Several	Many	Many
Ulmus pumila	Several		Several		Few	
Andropogon gerardi			Few	Several	Dominant	Dominant
Sorghastrum nutans					Several	Several
Bouteloua dactyloides		Several				
Festuca arundinacea		Many	Dominant	Dominant	Many	Many
Poa trivialis	Many					
	Other Notes	Other Notes	Other Notes		Other Notes	
	The Northwest aspect is heavily vegetated. The Southeast aspect looks like it has been recently widened.	More vegetation grows above the eastern roadcut, but there was more growing on the west side of the road. It is a new road cut, so it provides a good opportunity to take direct measurements of humidity and temperature.	For larger trees and shrubs, rooting typically takes place just above limestone. Additionally, there is a spring on the cut with the eastern aspect, and vegetation grows more heavily around the spring.		The trees and shrubs only grow on the face of the roadcut. There are not any growing above the road cut. This could be a result of the use of prescribed burns.	

The relatively abundant plant species located at each location did not change much across the sites surveyed. The most dominant tree species is eastern red cedar (*Juniperus virginiana*), a short growing but hardy native conifer. The most dominant grass depends on the location and the land management of the surrounding area. For example, the area surrounding the Seth Childs Rd. site is a fire-managed prairie, and so big bluestem (*Andropogan gerardi*) grows readily.

However, at the site on Juliette St. a form of bluegrass (*Poa trivialis*) grows, possibly due to spreading from the nearby residential areas.

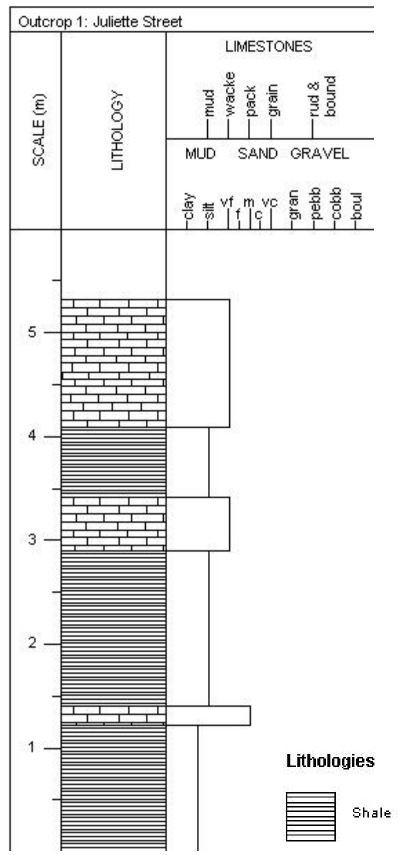
Anecdotally, it appears that vegetation coverage is in fact higher on the east facing cut than on the west facing cut for paired road cuts. Quantitative measurements of vegetation coverage were planned using the method utilized in a similar study conducted by Bold et al. (2010). Due to the time of year (early spring) when the survey was done, it was not possible to get a reliable quantitative measurement of the vegetation coverage. Therefore, this study cannot draw definitive conclusions on the relationship between aspect and vegetation coverage.

Wildlife

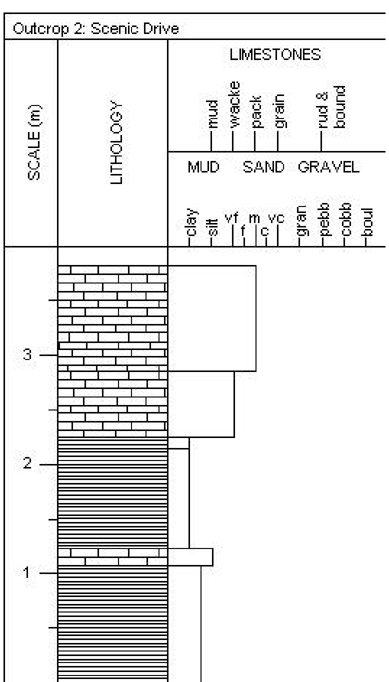
Juliette had 64 total individuals observed; 60 snails, 1 crow, 2 chickadees, and 1 owl. The Scenic Drive site had no evidence of animal activity. The East side of Tuttle Creek Dam had 3 wasp nests, 9 cicadas, and an unknown animal hole. The West side of Tuttle Creek Dam had 12 birds (of 4 different species), 8 moths, 1 wasp nest, 5 butterflies, 13 cicadas, 3 rollie pollies, and 1 unknown animal hole. The East side of Seth Childs had 5 butterflies, 7 cicadas, 2 birds, 1 rabbit, and 2 unknown animal holes. The West side of Seth Childs had 4 birds, 2 butterflies, 1 fly, 1 spiderweb, 5 cicadas, 4 unknown animal holes, and 1 ant hill.

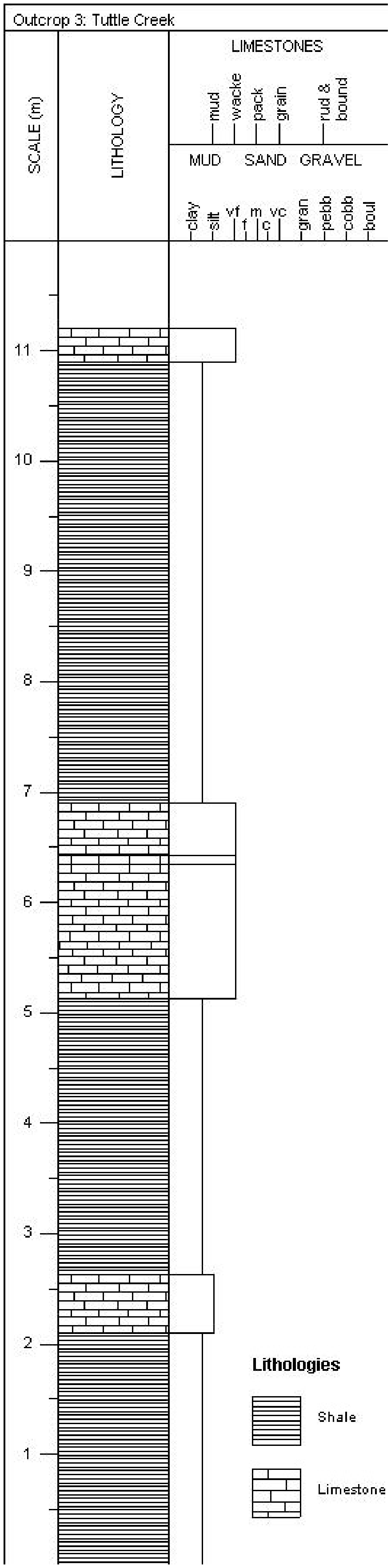
An “unknown animal hole” describes evidence of animal activity/burrowing, and a place in which an animal could live, but in which it could not be determined if it was occupied and by what species.

Structural Integrity

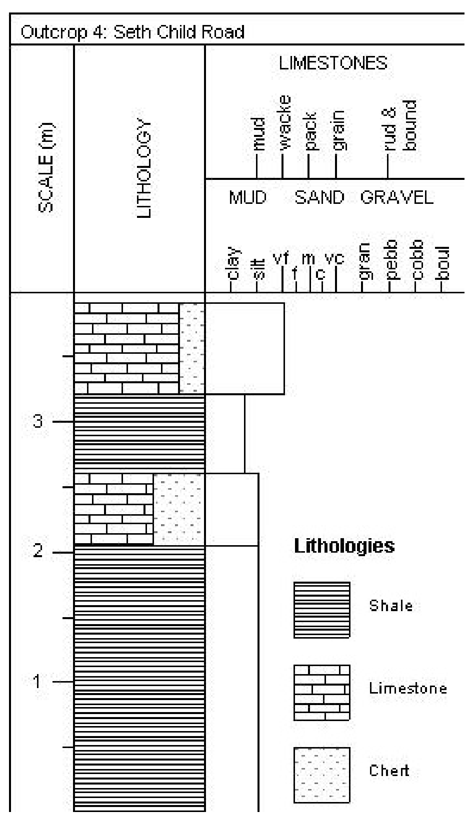


Juliette’s outcrop is 5.3 meters high and was six rock layers, alternating shale and limestone. Shale is the bottom unit and limestone is the top rock layer, with soil on top. The thickest shale layers is 1.49 meters, and this is the middle shale layer. The thickest limestone 1.23 meters, and the top layer before the soil. From the base of the erode shale to the road was about 1 meter. Shale at Juliette is the steepest with an angle of 50-55°, compared to the other road cuts. The shale does have plants growing. Since the shale is not sloping drastically, there is moderate overhang of the limestone. The rebound value (R value) was not able to be taken at Juliette.





Scenic Drive's outcrop was 3.8 meters tall and had six layers. These layers are also shale and limestone. Shale has about 50° slope, similar to the Juliette shale erosion gradient. Shale has a steeper slope due to new cuts, or maintenance. The shale at Scenic Drive has some plants not much. The road cut is too new to have significant vegetation growing in it. No significant overhang of the limestone here, but this can be attributed to the age of the road cut. Scenic Drive is the newest road cut we had observed. This road cut's limestone had the lowest recorded R value. A lower R value would indicate a weaker rock. Fresh rock faces are more vulnerable to weathering because of decreased hardness.



Tuttle's road cuts was 11.2 meters tall, and the tallest one we looked at. This road cut was made up of shale and limestone, and had eight layers. The shale here was a lot thicker than other road cuts. The shale was from 2-4 meters thick. From the base of the erode shale to the road was about 6 meters. Shale at Tuttle was 30-35°. Shale has been penetrated by plants and the shale was very fine grained mud. 2nd and 4th limestone layer had a significant overhang in some areas, except where it broke off completely. Overhang does significantly vary by length. East and west aspect of the road cut show similar R values.

The Seth Childs road cut was 3.9 meters tall. It alternated limestone and shale, and had four rock layers. The outcrop was about 7 meters from the base of the eroded shale. The shale at Seth Childs was 30-40°. This shale was more eroded than some that we have seen, and had a more gradual slope. Shale has been able to grow plants. Limestone has thin layer of soil on top that has also been growing plants, some fractures have been made by roots. The limestone had moderate overhang and chert inclusions. Limestone, over time precipitates chert which in turn hardens the rock and makes it more resistant to weathering. Out of the four road cuts this limestone had the largest R value overall.

Site		Shale Gradient	WG (σUCS)	WG-mean value (R)	ASTM (σUCS)	ASTM- mean value (R)
Juliette	U:	~50-55°	Invalid	Invalid	Invalid	Invalid
	M:		Invalid	Invalid	Invalid	Invalid
	L:		Invalid	Invalid	Invalid	Invalid
Scenic Drive	U:	~50°	Invalid	Invalid	Invalid	Invalid
	M:		4.94 MPa	11.5	18.7 MPa	30.5
	L:		5.12 MPa	12	11.45 MPa	34.5
Seth Childs- West Aspect	U:	~30°	Invalid	Invalid	Invalid	Invalid
	M:		Invalid	Invalid	Invalid	Invalid
	L:		Invalid	Invalid	Invalid	Invalid
Seth Childs-East	U:	~35-40°	3.13 MPa	5	100.3 MPa	54.5

Aspect	M:		3.36 MPa	6	24.7 MPa	34.5
	L:		Invalid	Invalid	Invalid	Invalid
Tuttle Creek Dam West Aspect	U:	~30°	7.80 MPa	18	57.3 MPa	45
	M:		7.01 MPa	16.5	49.8 MPa	44.5
	L:		4.94 MPa	11.5	51.5 MPa	46.5
Tuttle Creek Dam East Aspect	U:	~30-35°	Invalid	Invalid	Invalid	Invalid
	M:		Invalid	Invalid	Invalid	Invalid
	L:		4.30 MPa	9.5	59.3 MPa	47

Erosion

Juliette Road Cut

The outcrop at Juliette is a west facing but shows much more age. It is the most residential outcrop that we observed and has a lot of vegetation surrounding the top of the outcrop. Although there is a lot of vegetation the shale had the steepest gradient showing that erosion has taken a decent toll on this outcrop. The vegetation's root structures have also penetrated the surface of the outcrop contributing to the break-up of shale and limestone. Given this there is a decent amount of undercutting from the top layer of limestone with the combined rooting structures and shale and soil erosion from underneath. It also appears that the shale has a more fine loamy clay composition that seemed to retain a lot of moisture. The west facing outcrops in the rest of the observations did not show as much evident moisture retention as

Juliette did. This is most likely due to the fact that it is heavily shaded with less sunlight. As seen from the picture the erosion that has taken place could be somewhat scaled by the amount of limestone and shale along the roadside. Compared to Scenic Drive there is a drastic difference in the amount of sediment and limestone at the base of Juliette. There is also a large rill that runs along the roadside that is filled with sediment from the outcrop suspectedly. Juliette has a relatively decent amount of erosion from years of weathering and will continue to erode as the smaller shale and soil particles are washed away and the limestone is thus broken off by gravity.

Scenic Drive Road Cut

When observing this West facing outcrop it is evident that it is the youngest and most structurally intact outcrop that has been observed in the duration of this project. Some background on this outcrop is that around half of the exposed surface is limestone with more shale and soil composing the bottom half. This could potentially lead to large chunks of limestone being undercut in the future as seen in some older outcrops. But due to it age it has not had enough time to weather to a point where enough shale and soil has been lost to see any significant loss of limestone. Naturally with all the other factors discussed above there is minimal rill erosion or sheet erosion evident to the naked eye or deposited on the roadside. This outcrop also has a steep gradient or slope compared to all the others which is also a factor of being next to a recently constructed road. On top of the outcrop there is a large amount of vegetation that seems to help with retaining moisture and keeping some of the effects of water from eroding the outcrop. The topsoil is eroding from the edge of the limestone which could have an ecological impact on soil erosion and the vegetation on top of the outcrop in the future. Overall due to the age of this outcrop it would take a lengthy period of observations to get a gauge on the annual erosion as a function of time. Compared to the outcrops in this study, Scenic Drive shows that the structural integrity of this outcrop is still good and shows minimal indications of erosion.

Tuttle Creek Outcrop: East Facing

The outcrops at tuttle creek were the largest outcrops that we observed and appear to have a large amount of erosion in places and less in others. Part of this has to maybe do with some variances in the rock composition along the whole side of the outcrops. There was some vegetation along the outcrop but not enough to make a difference in erosion or a large effect from the rooting structures. From the pictures some of the outcrop has more limestone erosion from having more erodible soil and shale below the limestone layers. At the base on this side, there was a decent amount of limestone and shale deposits at the base and rills on both sides of the road. Compared to the west facing slope, there was more moisture observed on the face of this side. This could be a correlation to how moisture affects each side of the outcrops, which would thus be in relation to the aspect and weathering. From general observations it is hard to tell which side has truly eroded more per unit area, but given the average gradient amongst the other outcrops and the slope length and open face to weathering that this outcrop may be the most severely eroded out of the list of outcrops observed.

Tuttle Creek Outcrop: West Facing

There were a lot of similarities between the east side and this side. There was a a good amount of variation between gradient along the outcrop due to its length. There was also some variation in the undercutting of limestone from smaller sediment erosion depending on the slight variations of layers along the outcrop. There was also a good amount of water at the base of this outcrop that created a rill that carried sediment downhill. From this outcrop it was deducted that the gradient could change over time depending on the layers of limestone and shale because of the different erosion rates from larger sections of more erodible material such as shale or soil particles. So from this outcrop, some of the differences seen in gradient and erosion rates depend upon the inherent layers exposed in outcrops.

Seth Childs Outcrop: East Facing

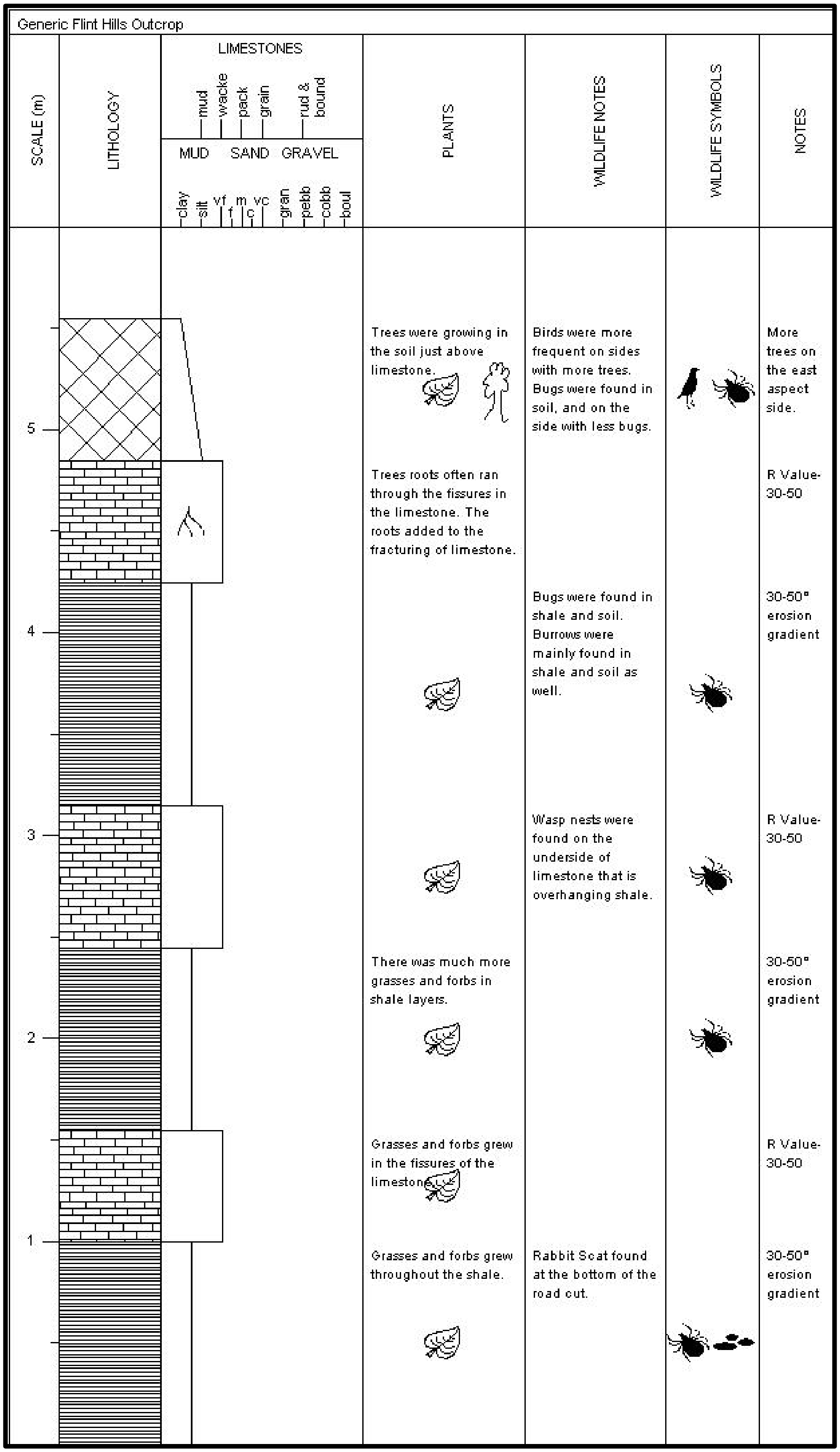
Both of these outcrops have the most gentle gradient and are the shortest outcrops that were observed during this study. Both sides had the most amount of vegetation actually on the outcrop since it had a more gentle gradient. As you can see there is a moderate amount of limestone undercutting and fracturing amongst the limestone. Another interesting factor is that the outcrop has two different levels or steps that are based on top of limestone. One conclusion that is made from this difference in structure is that the gentle gradient erodes the outcrop in a different manner than compared to a higher gradient outcrop such as Scenic Drive. Compared to the west facing side this side had less limestone and sediment at the base of the outcrop**.** The rill erosion at the base of the outcrop was also less evident and there was less retained moisture around the outcrop compared to the west facing side. Overall both sides seemed to be similar but based on the observations the east facing outcrop had less erosion than the west facing slope.

Seth Childs Outcrop: West Facing

The west facing outcrop at the Seth Childs was similar in structure and vegetation make-up but had some notable differences from the east facing slope that could lead to a proposal of more erosion taking place. As you can see moisture was one of the notable differences compared to the other side. This outcrop also had more limestone at the base as well as sediment deposited at the base in the rill which was full of water. From the observations, both outcrops had a decent amount of eroded sediment but that this side had indications of more deposits and maybe slightly less vegetation. At this point It is not evident if it is the aspect or the relation of the aspect to the weather and moisture patterns that erode them at possibly slightly different scales.

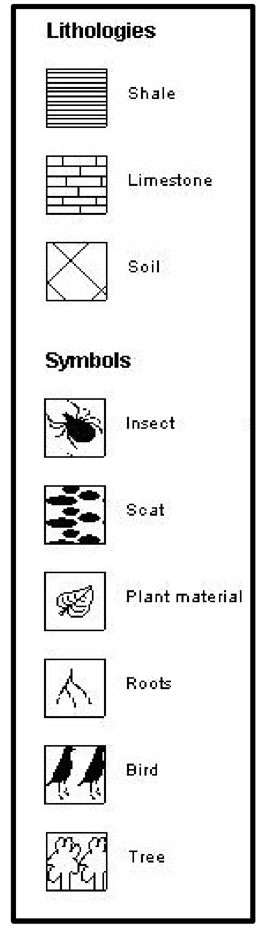
Summary of Results

Site	*Aspect*	*Shale Gradient*	*Most Dominant Vegetation*	*Animal - # of species*	*Animals - # of individuals*
Juliette	South	*50-55°*	*Juniperus virginiana*	*5*	*64*
Scenic Drive	West	*~50°*	*Festuca arundinacea*	*0*	*0*
Seth Childs- East Side	West	*35-40°*	*Juniperus virginiana*	*5*	*18*
Seth Childs- West Side	East	*~30°*	*Juniperus virginiana*	*7*	*14*
Tuttle- East Side	West	*30-35°*	*Andropogon gerardi*	*3*	*11*
Tuttle- West Side	East	*30-35°*	*Andropogon gerardi*	*9*	*41*


Generic Flint Hills Outcrop
SCALE (m)
LITHOLOGY
LIMESTONES
mud
wacke
pack
grain
rud & bound
MUD SAND GRAVEL
clay
silt
vf
f
m
c
vc
gran
pebb
cobb
boul
PLANTS
WILDLIFE NOTES
WILDLIFE SYMBOLS
NOTES
5
4
3
2
1
Trees were growing in the soil just above limestone.
Birds were more frequent on sides with more trees. Bugs were found in soil, and on the side with less bugs.
More trees on the east aspect side.
Trees roots often ran through the fissures in the limestone. The roots added to the fracturing of limestone.
R Value-30-50
Bugs were found in shale and soil. Burrows were mainly found in shale and soil as well.
30-50° erosion gradient
Wasp nests were found on the underside of limestone that is overhanging shale.
R Value-30-50
There was much more grasses and forbs in shale layers.
30-50° erosion gradient
Grasses and forbs grew in the fissures of the limestone.
R Value-30-50
Grasses and forbs grew throughout the shale.
Rabbit Scat found at the bottom of the road cut.
30-50° erosion gradient

Discussions

Vegetation



As stated previously, the time of year in which the study was done did not allow for a quantitative assessment of the vegetation coverage. However, it did visually appear that at the paired sites there was more vegetation growing on the east facing sides than on the west facing sides. This is consistent with the review of existing literature (Bennie, Hill, Baxter, & Huntley, 2006). If this is the case, then it would also be supported by the literature that erosion would be less on these east facing cuts than on their west facing counterparts (Halim & Normaniza, 2015).

In addition to taking direct measurements of the vegetation coverage, future studies could investigate the question of relative suitability for vegetation growth by measuring temperature and moisture content on the face of the road cut. One way to accomplish this would be to use iButtons, which are quarter sized instrument that takes measurements of different factors at a set interval. This data can be then used to interpolate which aspect is most suitable for plant growth, as water is a limiting growth factor and afternoon heat can stress plants.

It was noted that the age of the road cut and the management practices of the surrounding area (residential, fire managed prairie, etc.) seems to have a slight impact on the composition of the vegetation that grows on the road cut. This is consistent with a study conducted by Martin-Sanz, Fernandez-Santos, and Martinez-Ruiz (2015). However, the difference in composition is not significant as *Festuca arundinacea* and *Juniperus virginiana* were both found at nearly all sites. It is unclear if the slight difference in vegetation composition has an impact on structural integrity, but this could be a good area of future study.

Wildlife

The wildlife observations showed a larger number of species on the West side, particularly birds, than of road cuts than on their East counterparts, however, a larger number of insects on the East side than the West. This could be due to temperature variations, as well as habitat. It was also observed that there tended to be a higher number trees on the West side, offering birds more places to nest. On the unpaired road cuts, the surrounding vegetation appeared to have a larger impact on the wildlife in the area than any other factor, however due to the small sample size of this study, the correlation cannot be considered very strong. The site on Scenic Drive had no observations of animal activity. This may have been due to it's recent construction, not allowing time for wildlife to become established in the area.

These observations were made during a highly variable time of year in terms of weather events and temperature, which may have compounded wildlife observations.

Structural Integrity

The slope of the eroded shale varies from 30-55°. If the shale could be cut at an angle to begin with, it could prevent more erosion and limestone falling. The overhang limestones has nothing to support it up and fractures easily. This is dangerous since it could fracture and roll down the outcrop onto to road. The limestone would not need as much upkeep as long as it not dangerously overhanging a target or susceptible to plant roots that could cause further fractures.

The taller road cuts should be cut the farther it should be from the road. Ditches could also be dug between the road and the road cut. A ditch could catch eroded shale and falling limestone, or at least make it harder for this objects to slide on to the road. Calculate the amount of debris that is collecting below the road cut. Track the amount of precipitation and the direction from which it contacts the road cut. The aspect of the road cut in relation to the precipitation could possibly affect its erosion rate. Determine where the how much debris and where it has fallen from to calculate the rock mass strength of the road cut.

Some of the road cuts consisted of chert nodules. These nodules were found to increase the R value of the tested beds. It is unknown whether or not chert is still forming with time in the limestone beds. We know that chert is more resistant to limestone and takes much longer to weather. Further investigation on the subject could give us a better understanding if chert is currently being formed, and if the formation of new chert affects the overall strength of the rock not.

Erosion

While comparing these different outcrops based off general observation I observed some possible correlations that could use some further reasoning and study to prove their legitimacy. Future projects could answers the following questions:

- Does Kansas weather have an impact on which aspect and side of the rode an outcrop is facing have an effect on erosion rates?
- Does limestone, shale and soil composition of the surface of outcrops cause some to erode faster than others? Does the composition change the gradient as they erode over time causing other factors to accelerate erosion?

- What is the ecological impact of the rill erosion and sediment transfer downhill from highly eroded outcrops.

Future Study Recommendations

Due to the difficulties experienced in taking the different measurements required to make any determinations, we suggest creating a more long term study focused on one pair of road cuts. We believe that the ideal location would be one that was recently made, has not yet been densely vegetated, and has not yet been heavily eroded. Out of the locations already surveyed, the road cuts on Scenic Drive would provide the best opportunity for a long term study. Although the road cuts on Scenic Drive are offset (one sits north of the traffic light while the other sits south of the traffic light), they have been recently recut. Additionally, future studies should use a larger window of time for observations, noting any changes seasonally which could not be observed in this short study. Data and methods that can be utilized in future studies should include: the age of the outcrop, iButtons (used to collect temperature and humidity levels, useful for determining relative suitability for vegetation growth), erosion traps, motion detector cameras for wildlife, and timelapse photos to measure vegetation change, erosion change. Noting the traffic patterns and distance of the road from the roadcut could provide further data for continued studies.

Conclusions

The relative impact of factors that affect vegetation growth such as aspect and slope were not determined, but factors that affect vegetation growth like temperature and moisture can be determined at sites with different slope and aspect with the use of iButtons. Vegetation composition is subject to age of the outcrop and land use and management of the surrounding area.

The area in which a roadcut is located, and the surrounding vegetation have a high impact of the number and type of wildlife observed. Vegetation and rock type which offers more habitats for animals have a larger number of wildlife. The East and West side did have slight differences, although due to the small size of observations, it is difficult to determine the cause of these differences. Recent construction on road cuts deters wildlife from the area. Further studies are needed, with an increase in data collection, and possibly over a longer period of time.

It's best to cut the road outcrop as far back from the road as possible, for safety and because shale tends to have a slope of 30-50 degrees. Overhangs are dangerous. They can fall or roll. Best to maintain them, and also cut far back from the road. Digging a ditch between the road and outcrop can catch falling limestone or prevent eroding shale from getting on the road. Cut the road outcrop at least far enough back since the lowest shale layer could slide towards the road.

Due to the time period, the rate erosion can not be completely certain. Preliminary results shows that there might be some correlation between erosion in relation to aspect. Variations in moisture contents on the surface of the outcrops accumulated at the base. Some sides had more limestone and sediment deposits at the base of each outcrop which could be related to aspect and how erosive forces play on different facing slopes. When it comes to gradient steeper slopes with more limestone seem to be more resistant to erosion that outcrops with more shale and smaller soil particles and more gentle slopes. There could also be a more rapid rate of erosion in outcrops depending on the general composition of them. Outcrops with thicker layers of limestone have less shale and soil to undercut them. The composition has a possible impact on erosion rates that relates to the gradient and how it could possibly change as the different layers erode. Erosion seems to have some relation to aspect, as well as a relationship to how the weather affects the different facing outcrops might have an impact on the rate of erosion and moisture content.

There were various possibilities found that connect the aspect of the road cut to different rates of erosion susceptibility. Theses concepts provide the basic foundation for further studying on the topic. The above mentioned future study recommendations were established by the results and observations made in the field. Further studies are needed to better correlate the aspect to ecological health and erosion rates.

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