# Tracking the terrestrial “80 MA Sequence Boundary” in the subsurface and subsurface of northwestern Montana (Two Medicine Formation) and southern Alberta (Belly River Group)


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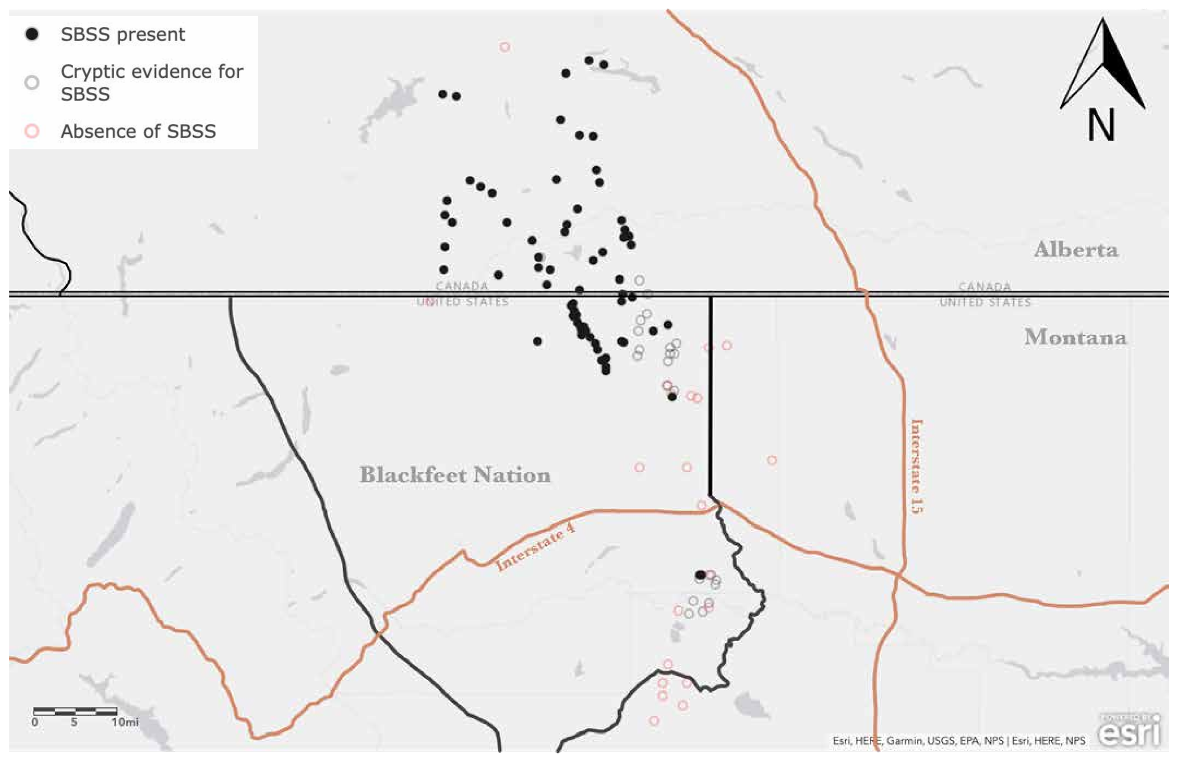
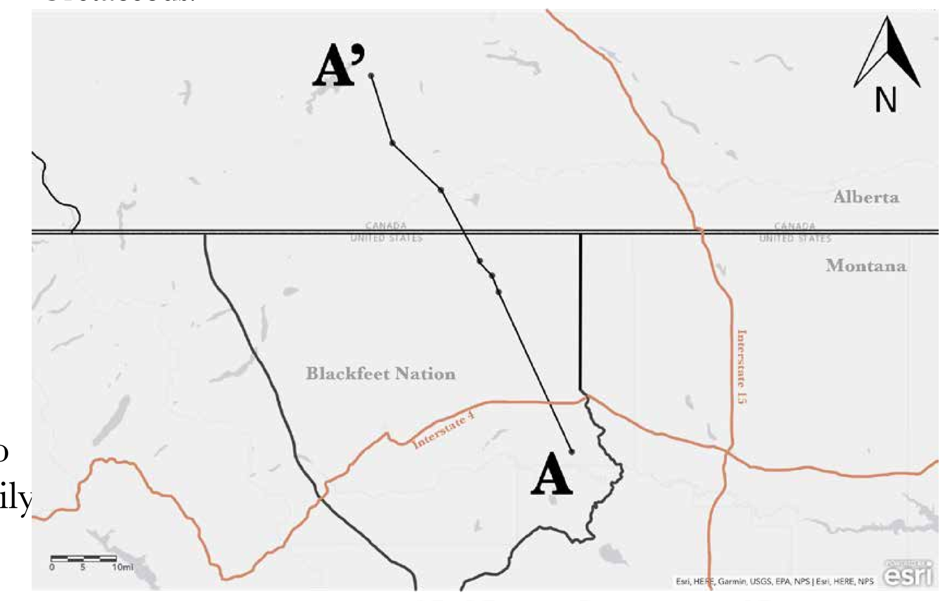
# Sequence-stratigraphic control on the nonmarine fossil record: a test in the Judith River Formation (Campanian) of north-central Montana



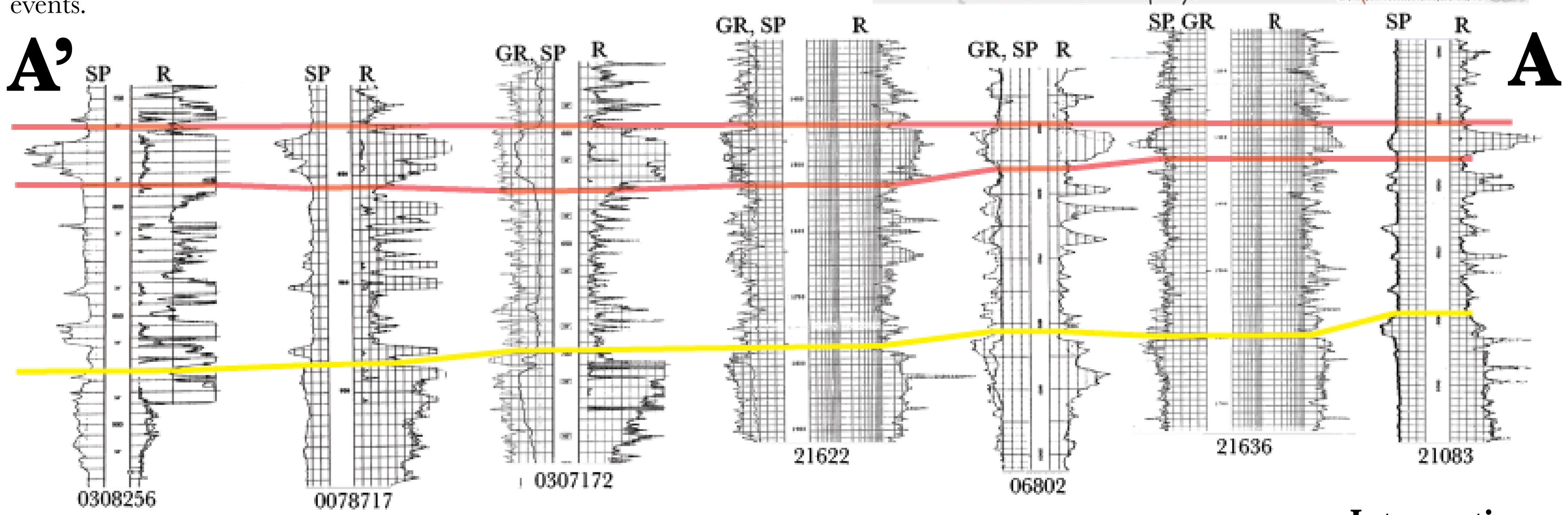

## Project Overview

I spent the first half of my summer exploring a set of geophysical well logs in the Two Medicine Formation in northwestern Montana and southern Alberta with the purpose of identifying and correlating an ~80 million year old sandstone body that represents a time of major geomorphic reorganization in the Western Interior Basin. This sandstone body, which represents an ancient river, was originally identified by my advisor, Raymond Rogers, in the 1990’s near Cut Bank, Montana, in outcrop as the non-marine expression of a period of relative base level fall in the basin at the end of a major marine regression (a fall in sea level). This outcrop exposure gives us ‘ground truth’ from which to base our subsurface investigation. After examining over 1500 well log records, we were able to track this unusual sandstone body more than 50 km north across the Canadian border, thereby demonstrating its widespread significance in the evolution of this region during the Cretaceous.




## How is the terrestrial rock record written?

Introductory sedimentary geology is based on the concept of actualism, meaning “the present is the key to the past.” If river system processes are the dominant terrestrial sediment transport mechanism on continent’s today, we assume that rivers were also important 80 million years ago. Thus, the terrestrial rock record is primarily compiled of sand deposited by rivers and silt/clay deposited by flooding events.



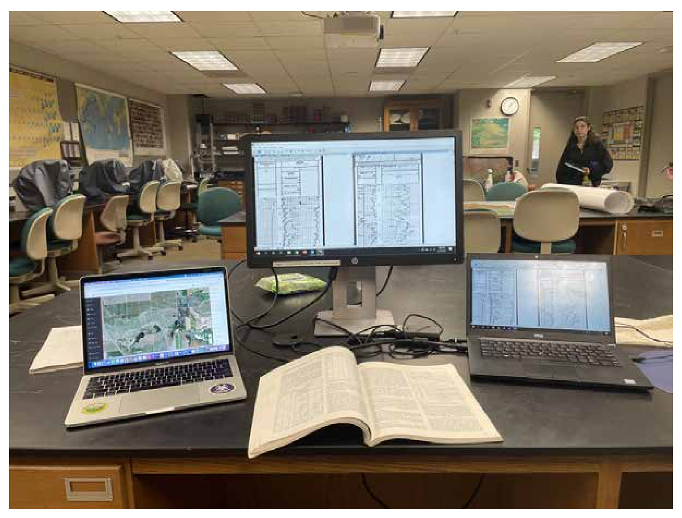

## How do geophysical well logs work? And what can we learn from them?

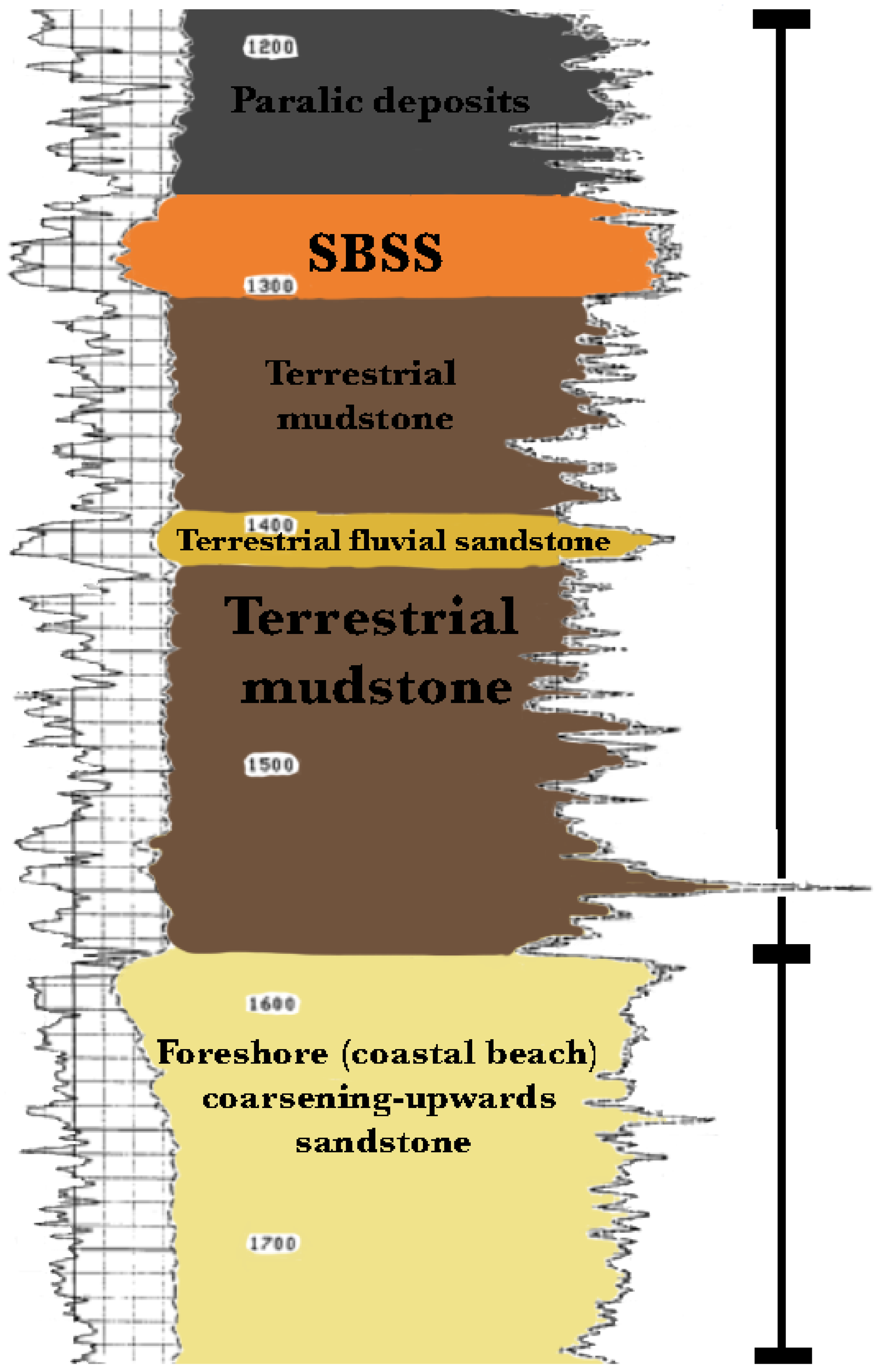
Geophysical well logs measure intrinsic physical properties of rocks below our feet which we can use to infer subsurface lithology. Though there are many types of measurements we primarily use three to determine lithology: spontaneous potential, gamma ray, and resistivity.

**Spontaneous potential (SP)** measures the difference in electric potential between the electrode in the borehole and a fixed point at the surface. An electrical potential is generated spontaneously in the borehole through the interaction between the fluid in the rock and the drilling mud. Coarser material such as sandstones allow for more exchange of ions and thus an SP spike away from the shale baseline.

**Gamma ray (GR)** logs measure the natural radioactivity in rocks. The primary radioactive elements are 40K, 232Th, 238U which concentrate in mudstones and shales. Thus, a deflection away from the shale baseline is another indicator of sand. **Resistivity (R)** measures the ability of a substance (rock in this case) to impede the flow of electrical current. More porous materials allow for the flow of interstitial water thus muds and shales resist flow better than sands. A spike away from the shale baseline may be another indicator of a sand body.

By combining these three measurements we can begin to understand the sequence of rocks below our feet.






### Interpreting well logs

Using well logs for geologic investigations is more quantity than quality. Unlike working on outcrop where data is limited but detailed, well logs present a cloud of data points, but the quality can be poor, and a geologist must learn how to prescribe rock types to a few squiggly lines.

In log 21746 to the left, the underlying Virgelle formation’s SP, GR, and resistivity, rise before sharply falling off. The Two-Medicine Formation follows with a series of terrestrial mudstones and sandstones. The “SBSS” is the sand body we are tracking in the subsurface and is distinguished by large, wide, SP, GR, and resistivity kicks approximately 280 feet above the Virgelle formation. Outcrop observations found that paralic coastal facies overlie the SBSS.

## Next Steps

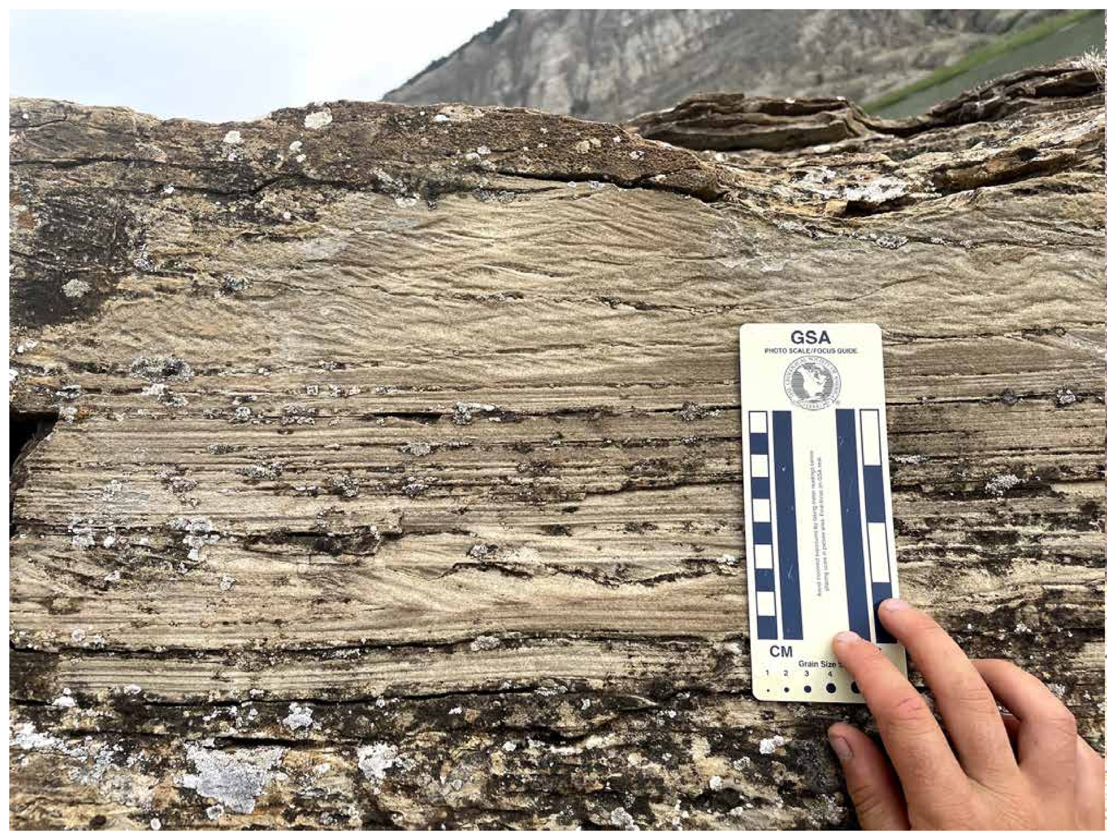
Use GIS software to create fence diagrams and a 3D representation of the sequence bounding sand body. These findings will be presented at the Geologic Society of America conference in Portland, Oregon this October. My senior honors thesis will be completed spring 2022.

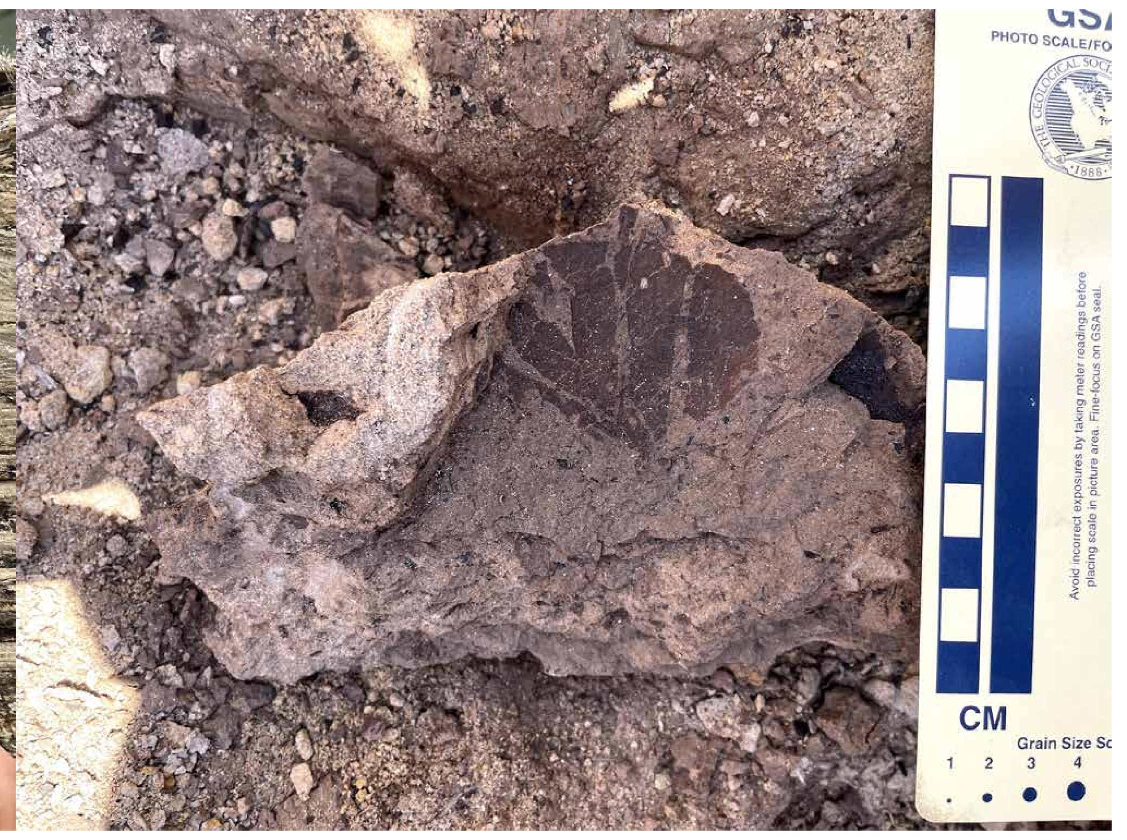
## Sequence stratigraphic significance

Sequence stratigraphy is the analysis of sedimentary deposits in a time stratigraphic context which are linked to the fundamental parameters of accommodation space and sediment supply. The SBSS represents a negative base-level adjustment during the Telegraph Creek-Eagle regression. While sea level fell, this ancient river system swept the floodplain of sediment, eroding and downcutting into itself as there was no accommodation space in the basin to deposit floodplain materials.

## Project Overview

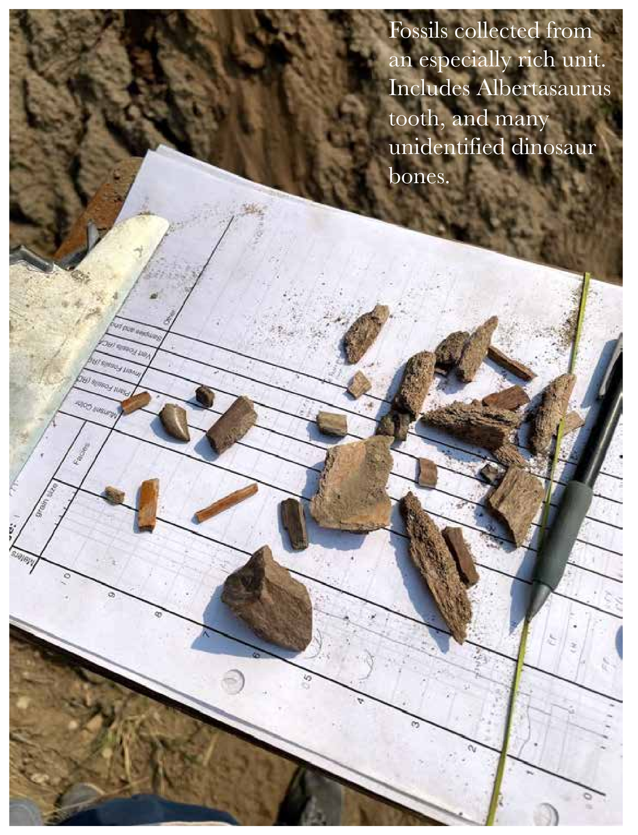
In the second half of my summer Professor Rogers arranged for me to serve as a field assistant for University of Georgia masters student Anik Regan (Macalester College geology major, class of 2017) in the Judith River Formation in north-central Montana. Anik’s project is focused on determining probability of fossil collection in different depositional environments across a major discontinuity in the Judith River Formation, which was identified by Rogers in the 1990’s when he was working on his dissertation in the same rocks. As a field assistant for Anik, I helped determine the depositional environment of each package of rocks we worked with, diligently searching for fossils along the way. I also gained valuable field experience that will serve me well in my future in a rugged and beautiful place - the Upper Missouri River Breaks National Monument.





## Stratigraphic Paleobiology

Anik’s work is the field of ‘stratigraphic paleobiology’ which uses a sequence stratigraphic framework analyze the distribution of fossils. Stratigraphic paleobiologists argue that stratigraphic processes need to be considered in addition to processes of evolution, ecology, and environment. In paleobiology, unlike the study of modern environments, time is often averaged over long periods and geologic conditions and the sequence in which sedimentary basins develop becomes much more significant in understanding past environments. If you stumble across a dense concentration of fossils in the field, it may not because a herd of dinosaurs all died together at the same time. It may be because of geologic processes which caused bones from across the plain to concentrate in one place.



Fossils collected from an especially rich unit. Includes Albertosaurus tooth, and many unidentified dinosaur bones.

## Anik’s work

Anik’s work in the Judith River Formation uses a statistical model to determine how depositional environments and large basin scale changes in accommodation space control fossil distribution. The section we worked in consists of ~140 meters of terrestrial rocks packaged in between two marine transgressions. Common rocks are cross-stratified sandstones, mudstones rich with plant fossils, and beds of coal. To collect data for Anik’s thesis we measured several hundred meters of vertical section of rock. As we climbed, we determined the depositional environment of each package of rocks and searched for fossils for five minutes in each package. Since our searches were a consistent time interval Anik’s model will compare fossil abundance, not how hard we searched. Anik is currently working on analyzing the data we collected in the field and will present her thesis this fall.


## Thanks and Acknowledgments

I thank Raymond Rogers and Kristi Curry-Rogers of Macalester College for the opportunity and funding to conduct summer research. Additional thanks to Raymond Rogers, Steve Holland, Anik Regan, and the University of Georgia for a tremendous field experience. Thanks to Kandy Walton, James Mitchell, Zane Fulbright (Bureau of Land Management), Jack Carr, Tom Philp for permits, shelter, and field supplies. Finally, thank you my parents, for everything.

*Special Acknowledgement to the Blackfeet Nation to whom much of the land investigated in this study belongs.*