****DRAFT****

** note: go back through statement and highlight areas where

- can tie in more w/ research being done already in geology dept and in the environmental studies dept.
- add in notes about the programs that exist to get undergrads involved in research that can be pulled from.
- add in more about using field sites and looking at things through a Minnesota lens

Research Experiences and Future Directions and Goals

I investigate carbon cycling on many different temporal and spatial scales to answer questions concerning what governs climate and why landscapes look the way we do. I approach these questions through a holistic lens that embraces the complexity of the natural world, recognizing that many processes are intertwined, and investigate the questions using hydrologic and geochemical techniques. My research is rooted in a critical zone framework which investigates the thin skin of the Earth on which we live that sustains our food systems stores water. Some of my driving research questions are: How much carbon does the critical zone sequester? How does changing land use and/or climate influence subsurface carbon storage? What are the mechanisms of carbon release and what controls them? How do you watersheds change with respect to carbon cycling in a changing climate? What is the influence of processes that impact climate on short time scales (e.g. subsurface respiration, microorganism activity) on processes that impact climate on longer time scales (e.g. weathering)? I am interested in these questions within specific environments and niches but also how they translate across vegetative, geologic, hydrologic, and anthropogenic boundaries. The tangible research and training experiences that I have completed, and plan to complete, are described below. These experiences will support an undergraduate-focused research program and provide a bridge between the Geology and Environmental Studies Departments at Carleton College.

Within the Geology Department at Carleton College, my research focus will be investigating the relationship between climate zone processes and climate. Within this research statement, I outline areas of research that I believe will be well-suited for undergraduate research that include field, laboratory, and computational components, allowing for flexibility depending on student interests and availability. These areas build upon my existing expertise, complement existing expertise within the Geology Department, and will pair well with learning objectives in planned coursework.

Ongoing carbon cycling research and training

My recent research focuses on carbon cycling in the subsoil environment, particularly in weathered rock. In upland systems, weathered rock can extend for tens of meters beneath the soil and host extensive root systems, store significant amounts of water even if it is unsaturated, and provide rock-derived nutrients. Although exchange of carbon with the atmosphere and soil is heavily studied, it is unclear if there is significant carbon dioxide production beneath soils and if respiration in this region is an important source of carbon dioxide to the atmosphere and to groundwater and streamwater. Through this research, I found that carbon dioxide production beneath soils is significant in upland forest ecosystems. I quantified the production within, and fluxes of carbon dioxide from, the weathered bedrock region, finding that respiration in weathered bedrock contributes up to 30% of CO_2 emitted to the atmosphere and up to 80% of dissolved inorganic carbon in groundwater (Tune et al. 2020, *in review*). This research involved multiple sampling campaigns to the field site in Northern California, many of which I led and during which I trained two undergraduate researchers and three different field technicians in geochemical and hydrological field sampling and analysis. This research also involved laboratory analysis of samples which the same undergraduate researchers assisted with. One of those undergraduate researchers participated through the Bridging Disciplines Program at UT Austin and went on to a career in the oil and gas industry, and the other participated to explore other scientific disciplines, ultimately going on to medical school.

In addition to quantifying current carbon processes that operate on daily to yearly timescales, my research also focuses on investigating carbon processes that operate on thousand to tens of thousands year timescales. I do this by probing the memory of these carbon processes that are preserved in the subsurface weathering profile. In particular, the oxidation of organic carbon preserved in rocks (e.g. shales, kerogen in glacial till) has been shown to be a source of carbon dioxide that is comparable to the sink of carbon dioxide due to silicate weathering and organic carbon burial over long time scales. These rates have largely been quantified in riverine systems, yet depletion of rock-derived organic carbon has been observed in weathering profiles across multiple lithologies, ecosystems, and climatic gradients. In northern California, we find that rock-derived organic carbon is depleted in the weathering profile beneath the bulk of the rooting zone and within the water table fluctuation zone (Tune et al. *in preparation*). While the rate of oxidation of rock-derived organic carbon is not relevant on yearly timescales as evidenced by radiocarbon analyses, it is clear that there is a connection between vegetation, hydrology, and oxidation of rock-derived organic carbon in hillslopes. This research is on-going in collaboration with the Eel River Critical Zone Observatory, University of Illinois Urbana Champaign, and the USGS.

Collaboration with the Critical Zone Observatory Program

My research is highly collaborative and involves many other researchers from different disciplines through the Critical Zone Observatory Program, particularly at the Eel River Critical Zone Observatory. These are connections which will be continued in my role in the Geology Department at Carleton College, allowing undergraduate researchers to form connections with potential graduate advisors, enrich their learning with different scientific perspectives, and connect to a larger research community. In addition, my collaboration with the CZO program also allows for greater access to data that can be used in course with significant project components in addition to other, open-source data such as SSURF, LTER, NEON, SSURGO, and USGS datasets.

Future Research Plans

A mechanistic understanding of upland subsoil respiration

While my previous research identified a seasonal dependence on subsoil respiration and fluxes, questions remain as to what is the mechanism that leads to seasonal differences in subsoil respiration. We hypothesize that respiration is driven by root activity and the surrounding rhizosphere, but have not directly tested this. I have procured grant funding from the Geological Society of America to install buried flux chambers and gas sampling ports in locations in Texas and California to measure gas concentrations and carbon isotopes. These will coincide with sampling infrastructure to measure water content, sapflow, and water table fluctuations. Due to the low cost nature of this sampling infrastructure, it can also be easily installed in locations throughout Minnesota where soils are underlain by bedrock and till. This is a great opportunity for undergraduate researchers who are interested in field intensive projects, environmental monitoring, and field experiences that involve travel. I anticipate that this infrastructure will sustain multiple years of analysis and be able to be used to approach additional research questions.

Prevalence of subsoil respiration across multiple litholgies and biomes

My previous and ongoing research has focused on subsoil respiration in forested, shale-dominated landscapes. However, there are many other regions with different lithologies and ecosystems where subsoil respiration might not only be different in magnitude, but also have different implications for weathering, solute generation, and therefore groundwater and streamwater composition. This project will involve field locations with established sampling infrastructure in California, Texas, and Colorado, and will be expanded to locations in Minnesota. This project will also have a non-field based component and use data from eddy-covariance towers to compare subsoil respiration to surface carbon dioxide efflux observations.

Production, transformation, and contribution of terrestrially-derived dissolved and particulate organic carbon to headwater streams and rivers

The delivery of dissolved and particulate organic carbon from the terrestrial surface is important for the functioning of aqueous ecosystems. Yet, the controls and mechanisms of transformations of organic carbon that occur before it reaches streams and lakes require more investigation in order to accurately manage natural and anthropogenic systems. Initial results from my research suggest that dissolved organic carbon is significantly chemically altered as it transits the unsaturated zone from soil to groundwater. This project will involve some sample collection, laboratory analysis, and hydrologic modeling. While a plethora of chemical analyses exist for tracking chemical changes in organic matter, one that is quickly gaining prominence is FTICR-MS. I have established connections to the team at Pacific Northwest National Laboratory to run aqueous samples through their FTICR-MS, and plan to develop laboratory techniques with undergraduate researchers to separate organic carbon by formula weight. In addition, there are multiple datasets of FTICR-MS data available through the PNNL SSURF program.

Weathering… subsoil co2 production

.. tie in with other Carleton professors

*The initiation of weathering by microorganisms*might leave this one out?**

Microorganisms are intimately tied to chemical processes in the subsurface, and microorganisms become progressively more important as depth increases and porosity decreases.