Research Experience and Future Directions
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What makes Earth a habitable planet? How will biogeochemical cycles change in response to ongoing climate and land use changes? And what can the geologic record tell us about how Earth responds to changes in environmental or geologic conditions when humans were not around? These central questions motivate my current research and future research directions, which I plan to address through field studies, model development, and geochemical analysis of rocks, sediments, water, and organic matter. The breadth of tools that my research employs will enable a diverse assembly of students to contribute where their interests or skills are strongest while equipping them with an understanding and appreciation of the various phases of scientific research necessary for successful hypothesis testing. The scientific questions and the methods by which my group will address them align with field-based learning, critical thinking, and multidisciplinary methods, dovetailing well with expertise within the Geology Department and fostering further collaboration with the Environmental Studies Department.

At Carleton College, I will build and expand upon my research interests regarding fluid-rock interactions, Earth surface processes, and the carbon cycle. Listed below are five projects that I plan to work on, three of which I have already contributed to during my MS and PhD research. Whereas my MS research was dedicated to understanding the Phanerozoic rock record of CO_2 output during metamorphism in continental arcs (Ramos et al., 2018; Ramos et al., 2020), my PhD research has been dedicated to understanding how different parts of the continental crust and associated surface processes influence silicate weathering (Ramos and Capaldi, *under review*; Ramos et al., 2019). Although seemingly disparate, my MS and PhD research manifest in projects that are largely centered around sample acquisition and field work, generation of geochemical and isotopic data, and development of numerical and/or statistical models that enable a process-based understanding of biogeochemical cycles and mass transport at the Earth's surface.

Past and ongoing projects

Silicate weathering and mass transfer in floodplains. Floodplains are hubs for silicate weathering and OC cycling at the Earth's surface, which make them important conveyors of nutrients that sustain ecosystems and enable agricultural development. Yet, little is known about where silicate weathering is greatest in floodplains and how geologic, environmental, and autogenic conditions in floodplains influence silicate weathering. Through geochemical and isotopic analysis of sediments and water in modern floodplains, stratigraphic and geochemical characterization of ancient floodplains preserved in the geologic record, and the construction of reactive transport models tailored to these observed systems, theory for floodplain weathering will be refined. These mechanistic models for floodplain weathering will further our understanding of why certain floodplains yield greater silicate weathering fluxes than others, translating to a better understanding of modern systems. Study locations to help build our conceptual and mechanistic understanding include recently deglaciated catchments of Minnesota and the Western United States.

Silicate weathering and Earth system responses to climatic perturbations and during hothouse climates of the past. Earth's climate has undergone significant perturbations that have changed surface environments and led to the demise of land and marine biota. These perturbations, often induced by pulses of CO_2 or methane from the solid Earth to the ocean and atmosphere, are usually followed by recoveries where climate returns to its pre-perturbed state. Although it is known that silicate weathering and organic carbon burial are the primary means that enable climate to return to its pre-perturbed state, the timescale of the recoveries vary significantly, which can be a function of hydroclimate, paleogeography, and the paleo-hypsometry of the crust. With targeted field campaigns in sedimentary basins that contain fluvial sediments, such as those within Laramide basins of the Western United States, benchmarked against global models for biogeochemical cycles that my group will develop, we will chronicle how and why Earth system responses to climate perturbations vary over geologic time.

Hydrothermal alteration and alkalinity sinks in old ocean crust. Although the continental crust is a dominant locus of biogeochemical reactions that influence global climate, marine basins and oceanic crust are another important center for reactions that can add or withdraw CO_2 from the Earth's surface. Reactions with oceanic crust were especially important during the Proterozoic eon when there lacked significant subaerially exposed continents. In studies of the alteration of oceanic crust, slow spreading centers or older oceanic crust are often disregarded because they are thought to be denser, less permeable, and less reactive crustal units. However, the proportion of the seafloor that is composed of old crust exceeds that of young crust adjacent to spreading centers. To test whether old crusts promote significant CO_2 drawdown through alkalinity fluxes, our group will develop reactive transport models for heat transfer and fluid flow in oceanic crust, benchmarked against geochemical and mineralogical observations of IODP drill cores.

Future projects

Linkages between the inorganic and organic carbon cycles. Silicate weathering and organic carbon (OC) cycling in soils respond to and affect climate on a range of timescales, from millennia to millions of years. While typically studied independently of one another, both weathering and OC cycling are intimately tied via the budgets of nutrients, acids, and reactive surfaces in soils. The result is a complex set of positive and negative feedbacks that make it difficult to predict how either weathering or OC cycling will respond to environmental change over a range of timescales. Moreover, the relationship(s) between weathering and OC cycling need not be the same across a landscape and may instead be modified by the physical processes operating on distinct landscape elements (e.g., hillslopes, floodplains, etc.). Our group will tackle this problem through novel geochemical analyses on soils, fluvial and lacustrine sediments, organic matter, and river water within watersheds around the US, particularly across lithologic and geomorphic gradients in Minnesota. These critical data are needed to test the hypothesis that secondary mineral formation is the primary control on silicate weathering rates and OC retention in soils. With these data and associated reactive transport models, theory will be developed that links the organic and inorganic carbon cycles spanning millennial to million-year timescales.

Silicate weathering during different phases of mountain building. Our understanding of silicate weathering is largely informed by observations of river water, sediments, and soils in river drainage catchments that are bounded by contractional or decaying mountains. The current paradigm states that areas where fresh, un-weathered minerals are readily supplied to the Earth surface are loci of silicate weathering. The development of relief in mountain ranges are known principal drivers of erosion and therefore modulators of silicate weathering. Exhumation of fresh minerals can occur during various stages of mountain building, including shortening and extension, but the current body of literature has focused predominantly on contractional environments. Extension is an energetically favorable mode of tectonic activity and may thus be an important process involved in silicate weathering at the Earth's surface. Yet, theory for silicate weathering during extension is lacking. My group will develop functional relationships for silicate weathering during extension in modern environments and assess how silicate weathering differs between phases of extension and contraction during mountain building by studies of sedimentary basins that formed during extension and contraction. Field locations include the Basin and Range region of the Western United States, which has undergone periods of protracted extension.