**Research Experience and Future Directions**

How and why are polar and alpine landscapes changing? What sedimentary paleoclimate records will be lost when permafrost thaws and can we salvage them? How can we use knowledge of climate and surface processes on Earth to understand if Mars was ever “warm and wet”? And why do the poles matter for people who live in the temperate zone? My research aims to answer these kinds of questions by investigating the structure, origins, and future responses of polar and alpine landscapes to changing climate conditions using satellite observations, embedded sensor networks, and laboratory analyses of sediments, water, organic matter, and ice. This wide range of technical approaches is synthesized into a probe of surface composition, climate history, and future response through remote sensing and GIS analyses. “Polar geology” conjures up images of epic expeditions, grizzled scientists, and graduate students exiled to the cold and empty parts of the world. While this romantic view of polar geoscience has some historical truth to it, it is not a complete picture of how I use polar and alpine field experiments to support an undergraduate-focused research program. I believe that the combination of research and training described below would be a natural fit into Colgate’s ongoing commitment to field-based research and training.

In the Geology Department, my research will continue to focus on exploring how climate information is recorded in sedimentary landforms, and on using real-time studies of changing landscape geomorphology to understand the impacts of climate change on the Earth’s surface and ecosystems. I have four ongoing research areas that are ideally suited for participation by undergraduate student scientists who will help collect field data over winter and summer breaks, analyze the observations during the academic year, and in turn, learn about the interactions between climate and the Earth surface. These projects combine opportunities for both local fieldwork in the northeast U.S. and international fieldwork in Antarctica or the Arctic, hands-on sedimentological and soils analysis in the lab, and computer-based geomorphic analysis—making them ideally suited for students who have different amounts of time to commit to research, different levels of interest or comfort in the field, and different learning goals. These new research directions (next page) build on my existing research strengths in cold regions geomorphology and climate processes and harness them to produce life-changing research and learning opportunities for Colgate students.

**Ongoing Antarctic Research and Training.** Over the last several years, my research has focused largely on the relationships between Antarctic regional climate and the formation of thermokarst (ground subsidence and slope failure due to the melting of buried ice). Thermokarst erosion is common in the Arctic but is beginning to occur on an unprecedented scale in Antarctica, where it is disrupting key paleolake deposits used to reconstruct past ice sheet conditions. With the help of the two UT undergrads who have joined me in Antarctica (and three others who analyze field data in the lab), I am working to constrain the causes, rates, and consequences of Antarctic thermokarst formation. We are using a diverse set of tools to tackle the problem, including repeat LiDAR and photometric measurements to determine the modern rate of change in these collapsing landscapes, regional meteorological observations to identify the climate drivers of melt, and geochemical analyses of sediment, buried ice, and the resulting meltwater to determine how salts are acting as “antifreeze” in the regional hydrological system. Most importantly, we are using traditional analyses of stratigraphic section combined with cutting edge OSL geochronometry to extract a new understanding of the depositional regime surrounding the Ross Sea ice sheet during the last two major glaciations (before these deposits melt and are gone forever). In this manner, my research links climate processes (insolation, precipitation, and heat transfer in the subsurface) to sedimentary geomorphology and hydrology in polar permafrost environments. This work evolved from an NSF Polar Regions Research Postdoctoral Fellowship into two funded NSF Antarctic Earth Science awards to use field measurements and remote-sensing of polar landscapes to predict how Antarctic surface processes will evolve in a warmer, wetter world.

Undergraduate researchers (Jaclyn Watters and Logan Marcos Schmidt) have contributed immensely to this project through diligent fieldwork, analysis of time-lapse image data, and laboratory analysis of the thermal and hydrological properties of Antarctic soils. As a consequence, they have contributed as authors to some of the highest-profile manuscripts to emerge from the project (e.g., Levy et al. 2013 in *Nature’s* open-access journal, *Scientific Reports*). This project also led to my ongoing collaboration with Lily Simonson, a California-based painter and NSF Antarctic artist fellow who has worked in the field with me since 2012. Lily’s paintings of polar landscapes help connect the arts community to the rapidly changing state of polar and alpine permafrost by vividly capturing the magnitude and consequences of thaw. Interactions between artists and students in the field help show that there are many ways to observe a landscape, capture its important properties, and communicate one’s findings.

**Interactions with the Long Term Ecological Research Program.** I am a collaborating investigator on the McMurdo Dry Valleys Long Term Ecological Research project (MCM-LTER). This ongoing project will allow me to continue investigating the response of cold landscapes to perturbations in near-surface energy balance and water budgets, particularly perturbations that are driven by regional climate change and biological feedbacks. I am working to develop long term permafrost and active layer monitoring as part of the MCM-LTER core dataset. The investigations focus on linking the physical mechanisms of water and solute cycling through cold-desert sediments to detailed studies of climate-driven surface energy balance. Through collaboration with the LTER, I will be able to bring students to the field to conduct Antarctic research between terms, and will be able to capitalize on partnerships with affiliated scientists at research universities who will help maintain my experiments during the academic year.

**Planetary Science.** I look forward to bringing two current NASA projects to Colgate that revolve around laboratory simulation of erosion (on Titan) and sediment redistribution (on Mars). The “Titan Tumbler” project is a benchtop experiment aimed at understanding the fundamentals of ice cobble erosion at liquid-nitrogen temperatures (to simulate erosion of water ice rock in Titan’s hydrocarbon rivers) and provides a space-age perspective on the foundational experiments in terrestrial erosion research. The Martian “boulder halo” project is a data analysis effort that would allow Colgate students to use high-resolution imaging data from Mars to study the formation of enigmatic rings of boulders that dot the Martian lowland plains. These projects highlight the ways in which I use planetary science to explore and teach about fundamental sedimentary and geomorphic processes. Both projects have support for undergraduate researchers to conduct experiments, make observations, and to present their results at national meetings. Appointment as an assistant professor would allow me to activate my NASA Early Career Fellowship (associated with the Titan Tumbler), giving me the opportunity to request up to $100k from NASA for funding to support student travel for sample collection, analysis and equipment, and presentation of results.

**Future Research Plans**

**Planetary-Analog Sedimentology in the Ice-Age Appalachians.** Colgate’s location at the interface between the glaciated northeast and the unglaciated ranges to the south makes it an ideal base from which to explore the geological record of ice-sheet and near-ice-sheet hydrogeology at the close of the last ice age. A new twist on this classic research area would be to use this key landscape interface to support planetary analog research directed at understanding how different runoff sources—snow, rain, and proglacial melt channels—are preserved in the landscape. This is a key question in Mars science today—do valley networks on Mars indicate “warm and wet” rain-dominated conditions or could they have formed from “cold and wet” snow runoff and/or ice-sheet melt? Through academic year field trips and short excursions with students, I look forward to mapping water sources and routing during Pleistocene glaciation. By combining this ground-based research with Shuttle Radar Topography Mission digital elevation models and existing LiDAR data, this project would compare drainage network geomorphic characteristics and deltaic deposit structure between watersheds dominated by ice-sheet runoff, with watersheds dominated by snowmelt runoff in the adjacent, unglaciated watersheds, and with runoff from rain in watersheds that are fully outside the Pleistocene glacial zone. This would provide key information about how runoff sources shape channel characteristics in the rock record and would provide key insights for interpreting the history of Martian valley networks.

**Polar Delta Geomorphology:** **The Fingerprint of Ice.** Polar and alpine deltas are extremely sensitive to climate-driven changes in discharge and basin conditions, however, they have received very little attention as markers of past climate change or as indicators of modern perturbations at the catchment scale. Building on flume experiments conducted at UT-Austin that have shed light on how ice-affected deltaic deposits differ from deposition in ice-free basins, I have a pending first-round proposal in to NSF to support sonar imaging of deltas in the Alaskan arctic and Antarctic to determine how sedimentation is changing in response to the loss of sea ice cover. Ideally, this sedimentology/geomorphology project would be followed up by expeditions closer to home (e.g., the Finger Lakes) to use imaging and shallow core collection to determine when lakes along the Laurentide ice sheet fringe became ice-free. These nearby surveys would be an ideal training opportunity to students interested in joining summer or winter expeditions to the poles, and will provide a trove of locally-relevant samples and data for classroom analysis projects.

**Antarctic Carbon in a Changing World.** As Antarctic land ice retreats and thins, a continent of soil and rock is emerging from beneath the ice that has been mostly buried for the last 34 million years. The mechanisms and rates of carbon enrichment in Arctic soils at the end of the last ice age are well known, however, nearly nothing is known about how carbon enters ancient, saline Antarctic soils and what impact this will have on global carbon budgets as a continent’s worth of land area becomes available for terrestrial primary production. Collaboration with Colgate’s environmental studies group would be an outstanding opportunity to study the rates and mechanisms of carbon uptake by Antarctic soils and would help answer the pressing polar climate and ecosystem question: what will Antarctica’s role be in global climate and carbon cycling after the ice is gone?

**Mountain West Debris-Covered Glaciers: Water Resources and Local Paleoclimate.** Debris-covered glaciers (DCGs) and rock glaciers are an enigmatic landform whose importance as an alpine water resource and as a repository of paleoclimate information is just beginning to be recognized. DCGs preserve buried glacier ice long after un-insulated glaciers have ablated. They preserve a lingering record of glacier advance and retreat in their many lobes, folds, and scarps, as well as a slow-melting core of ice that feeds local watersheds and powers alpine meadow ecosystems. I look forward to continuing my collaborations with a multi-university team that is examining these important landforms by providing the drone-based photogrammetry, topography, and geomorphic analyses needed to interpret ongoing radar and EM-induction studies of the internal structure and composition of DCGs in Alaska, Wyoming, and Utah. Colgate students would gain an opportunity to join me in summer trips for field mapping and hyperspectral imaging, as well as academic year trips to visit remnant DCGs in the nearby White Mountains. Through my ongoing collaborations with the Utah State University Optically Stimulated Luminescence dating laboratory, students would also gain experience collecting and analyzing samples using this cutting-edge geochronometer to relate DCG deformation patterns to local climate chronologies derived from alpine ice cores. Exploring these features in the mountain west will connect Geology students to an emerging climate repository as well as to an important conservation feature that affects communities in our country, but also in developing nations along the Andes and Himalayas.