Personal Statement, K. Kochanski

Human societies are deeply shaped by the landscapes around them. Colorado's roads, for example, follow river-carved valleys through the Rockies. Those same rivers send water and soil down to the fertile Midwestern Plains. In turn, those farmlands rely on the snowfields of the Antarctic that, far away and untouched by humans until 1895, reflect solar radiation and keep our climate mild.

I became a geomorphologist to study natural processes like these. My first goal is to protect our society by increasing the scope and accuracy with which we can predict environmental change. My second is to create and share a truly global Earth Science across all cultural barriers.

1 Discovering Geology

Earth Science crossed my intellectual horizons in my second year at MIT. I was then majoring in Physics and working in an astrophysics lab, where I **calibrated a prototype x-ray polarimeter**. I enjoyed working with optics, and successfully tripled the machine's throughput, but I had started to lead hikes with the MIT Outing Club and wanted to learn what was under my feet. I took Introductory Geology and have been captivated by geoscience ever since.

My first geoscience research project began immediately afterwards, in January 2013 . Under Prof. Leigh Royden. I **built a 3D model to predict the flow of material under the Tibetan Plateau**. We estimated that modern topography could only be formed if the lower-crustal viscosity was less than $10^{17}\mathrm{Pa}\cdot\mathrm{s}$. This project introduced me to fluid dynamics simulations and to Matlab.

That summer I **worked as a field assistant in the western Himalaya** under Prof. Oliver Jagoutz and his student Ben Klein, with funding from the MIT-India program. We surveyed the Khardung volcanics for sample sites for a paleomagnetic study. We took cores from three sites [1]. The results have now been used to constrain the rate of the Indo-Asian collision [2]. My notebook from that trip is full of lines like "Why are the granite slopes so steep here?" or, "How do streambeds form in these mountains of colluvium?". Geology gave my questions a language.

In the fall I **declared a double major in Earth Science and Physics**. I chose electives that would help me analyze the natural world: Statistical Mechanics, Classical Mechanics through non-linear dynamics, and Experimental Physics. Alongside my core classes I took Prof. Taylor Perron's Geomorphology course, seeking answers to my questions about weathering, streambeds, and glacial valleys. His descriptions still snap into my mind when I encounter a new landscape.

In January 2014 I **mapped the Piute Mountains** with five other students for a field course. The area, a part of the Mojave Desert, has a deformed metamorphic core complex which had never been mapped in detail. Grappling with it taught me to visualize complex 3D structures and to communicate them to my partners, but what most interested me was the effect the deep structures had on the surface. Early in our course, Prof. Jagoutz and I followed a fault to a high ridge. We spent our lunch break analyzing the curvatures of the hillslopes below, and trying to differentiate quartzite colluvium from finer-grained schist debris by slope angles alone.

In the winters I slowly fell for the delicate beauty of ice, which clings like crystal chandeliers to the frozen streams and branches of New England. I grew more involved with the MIT Outing Club and volunteered to lead regular hikes and maintain the club's gear. These hikes let me show beginners how to dress warmly and travel on snow-shoes so that they too could find joy in the cold.

2 Published Research Projects

2.1 Floating objects in Smoothed Particle Hydrodynamics (SPH)

My junior summer I took a fluid-dynamics focused internship at Shell's Technology Center in Bangalore. The summer had a difficult start. Visa problems forced me to fly back to the US after three days in India. To prepare for my project while waiting for paperwork, I learned C#.

At Shell I **developed a SPH code** to simulate the movement of floating objects in free-surface flows. Our test case was the impact of high waves on an offshore oil tanker. My task was to generalize Shell's in-house C# code to model multiple floating objects. During this process I discovered a problem with our boundary conditions during collisions, and modified the solver's search algorithm to prevent non-physical behavior.

My group **published our work** at an international SPH workshop in June 2015. Shell will use the results to **improve rig safety** and **reduce the risk of oil spills**. This experience with simulated floating particles will be very useful for my future research. Suspended sediment is an important part of many natural systems, including wind-blown snow. That summer I also met colleagues from across India, and learned how to wear an elegant dupatta and to brew spicy chai.

2.2 Ice Accumulation on GPS stations in Alaska

For my senior thesis, supervised by Prof. Thomas Herring, I aimed to use geodetic data to **analyze how 2015's warm winter affected Alaskan hydrology**. Warm rainfall runs off the land faster than snow, depriving spring vegetation of water, and increasing weathering rates and groundwater acidity. GPS stations can measure hydrology because the weight of water depresses the ground by 5-10mm seasonally. Stations in southern Alaska reliably oscillate in phase with snowfall [3]. I looked for recent changes in the movement of fifty GPS stations across the state.

Instead, in Northwest Alaska I **found that six stations move out of phase with snowfall** by over two months, with vertical amplitudes from 4-15mm. In winter these six stations move discontinuously, jumping over 10mm/day, and they have unusually asymmetric time-series. I formed several hypotheses for these discrepancies, including pressure fluctuations, thermal expansion, or localized loading by lakes or sea birds. However, the stations' horizontal movements were inconsistent with these hypotheses. Finally, I discovered that three of these stations are on high points on Alaska's west coast. They suffer high winds and humidity, and should accumulate thick rime.

Prof. Herring and I **demonstrated that horizontal rime causes GPS stations to appear to move vertically** by simulating signal delay in icy rime feathers using Matlab. Using multipath data, I confirmed that the signals were more scattered in winter than in summer, and verified our results by using wind speed directions to predict rime orientation at each station, confirming that these stations' apparent winter motion is indeed caused by signal delay in ice.

This project let me apply my statistics and data analysis skills to a research problem of my own. The results will **improve geodetic and hydrologic measurements** in cold climates. I will **present them at the AGU 2015 Fall Meeting** and am **preparing them for publication**.

3 Sharing science

I believe that my first responsibility as a scientist is to **communicate rigorous science**. At MIT I refined my communication skills with a Writing concentration. In addition, for three semesters I taught twice-weekly recitations for a writing-intensive philosophy class. The first semester, some students wrote incoherent midterms. To improve the class the next year, I designed three academic writing workshops, after which all my students wrote clear and effective essays.

To share my research with the public, I **give frequent public outreach lectures**, and maintain a non-technical geology blog [tinyurl.com/blog-geo]. I love to show people the world from a new perspective. My favorite lecture starts with a photo of a marine fossil from the high Himalaya, one thousand miles from the sea, then explains how it got up there. In 2015 I **received MIT's Suzanne Berger Award for Future Global Leaders** for my success in India, with both fieldwork and computational research, and for the enthusiasm with which I shared my experiences at home.

Last year I **attended the American Geophysical Union's Fall Meeting**. Presenters demonstrated an amazing array of tools, from Lidar to image-processing, which they had applied to study the Earth. I look forward to presenting my thesis there this fall.

4 Inspiring future scientists

Last summer I **taught real research skills to high school students** by working with six MIT students to organize the first Chilean Young Physicists' Tournament (YPT) at two public schools in Santiago [iyptchile.wordpress.com]. Teams of students investigated simple, unsolved problems. To progress, they reviewed literature, designed experiments, and presented their findings. My role was to design our curriculum and to mentor a team.

The local teachers were on strike when we arrived in Santiago, and the school was occupied by protesting students. I immediately **negotiated to secure lab space**. As normal classes were cancelled we arranged to teach for four hours each day for seven weeks, working in Spanish.

My students were eleven young women who had never had a hands-on class before. Our first project was to mix salt and sugar water. At first, students mixed the liquids arbitrarily, but eventually they designed a series of experiments in which they varied saltwater densities to investigate double-diffusive convection. I began to overhear, "wait, which hypothesis does that test?" and realized that they had begun to internalize the scientific process.

Between classes, the students helped me. I **learned scientific Spanish**, and how to find meeting space in Santiago when floods closed the school. Four students have now entered a chemistry competition with a plan to combat Santiago's smog. Their schools are under-funded and unreliable, but they are fighting for their educations, and I am more than proud to have helped them.

5 Future goals

CU-Boulder's Department of Geological Sciences is home to exceptionally lively geomorphology and Arctic research communities. Here, I have support to develop both my quantitative skills and my understanding of the Earth. My peers share my love for the science of the natural world and encourage me to pass that love on to younger students.

To use my Spanish teaching experience and **engage with Hispanic students**, I have volunteered to be a science fair judge for the Bryant-Webster Dual Language ECE-8 School.

My main outreach project is to **create a local Young Physicists' Tournament**. To begin, I will design and teach a weekly YPT course this winter. Teams of 3-5 students will undertake open-ended science projects, such as to pull a horizontal frisbee out of a water trough and investigate the vortices beneath it. I have discussed this plan extensively with CU's Science Discovery, who are excited to host a new hands-on course. We are aiming the class at home-schooled students, who typically have few opportunities for team work.

The International YPT draws teams from 30+ countries, but the USA has participated only once since 2006. I have talked with two other fledgling US YPT groups. We hope to collectively field an international team in 2017 to **develop the next generation of globally engaged scientists**.

My two major career goals are to improve our scientific and public understanding of our environment, and to inspire younger scientists who will develop that understanding even further. I am pursuing those goals with every resource available to me through CU. An NSF GRF would give me financial freedom to focus on my work until I attain them.

[**1**] Bailey, E. & Weiss, B. B.Sc. thesis, MIT, 2014. [**2**] Jagoutz, O., Royden, L., Holt, A.F. & Becker, T.W. *Nature Geoscience*, **8**, 2015. [**3**] Fu, Y., Freymueller, J.T. & Jensen, T. *Geo. Res. Letters*, **39**, 2012.