A new geochemistry course with applications in Earth, Marine, and Material Science

Introduction

The field of geochemistry applies the principles and techniques of chemistry to understand the evolution of the Earth's lithosphere, hydrosphere, and atmosphere, as well as, the formation of the solar system. Geochemical principles span the Earth disciplines to address numerous problems including: the measurement of geologic time, the composition and evolution of the Earth interior, the exploration of economic resources, the evolution of neighboring planets, and humanity's impact on our environment and climate. Few other disciplines can claim to address such a diverse array of scientific problems, and yet, there is no current geochemistry course offering at Western.

I propose to use salary from the Summer Teaching Grant to develop an advanced undergraduate and graduate course in geochemistry (GEOL 461/561) to be taught in the Fall of 2019. Students enrolled in the course will learn to evaluate the role of geochemistry in studying the evolution of our planet, interpret the behavior of naturally complex geochemical systems, and predict the outcome of geochemical processes. To achieve these outcomes the course will combine student-centered class sessions with quantitative problem sets and analytical laboratory exercises using instrument facilities within Geology, AMSEC, and SciTech. The course will benefit undergraduate and graduate majors throughout the Geology program by providing a quantitative geochemical foundation and valuable experience using state-of-the-art instrumentation that will increase their competitiveness in future career and academic pursuits. In addition, the course can be cross-listed to serve students in the upcoming Marine Science Program and the proposed AMSEC Material's Science M.S. program.

Description of intended work

The proposed geochemistry course will cover the fundamental geochemical principles of thermodynamics, reaction kinetics, elemental diffusion, and stable and radiogenic isotopes. These topics will be taught throughout the course through a progression of geochemical systems beginning in the Earth's deep interior and lithosphere and then progressing upward through the hydrosphere, atmosphere, and ultimately the solar system and galaxy. The topics covered across these geochemical systems will range from the formation of distinct chemical reservoirs within the Earth, mineral equilibrium and responses to changing pressure and temperature, the kinetics of diagenesis and chemical weathering, evolution of the atmosphere and oceans, and estimating the bulk composition of extraterrestrial planets.

I will use the Summer Research Grant to develop a series of problem sets and laboratory exercises for the course (see examples below). The laboratory exercises, in particular, require significant effort outside of the normal course development effort to collect and prepare samples and design successful experiments. The labs will use the modern analytical tools of geochemistry, including: scanning electron microscopy (SEM-EDS) in SciTech, (laser-ablation) inductively-coupled plasma mass-spectrometer (LA-)ICP-MS in AMSEC, and the newly funded x-ray diffractometer (XRD) in Chemistry and Geology.

Example problem sets to be developed:

- Energy, entropy and fundamental thermodynamic concepts
- Estimating thermal and chemical fluxes in the Earth's interior with incompatible elements
- Determining the first appearance of water on Earth using radiogenic and stable isotopes
- Global mass balance within the ocean and atmosphere using major elements

Example lab exercises to be developed:

- Estimating magma compositions from mineral trace element concentrations (LA-ICPMS)

- Measuring cooling rates from elemental diffusion profiles in silicates (SEM-EDS)
- Chemical weathering rinds on basalt and implications for soil formation on Mars (XRD)
- The extant of natural versus anthropogenic contamination of water supplies (ICP-MS)

Explanation of project's importance and methods to be utilized

The proposed course will expand my teaching expertise and build upon active learning and inclusive teaching practices gained through my professional development experience in the Howard Hughes Medical Institute (HHMI) Advancing Excellence and Equity in Science (AEES) program at Western. As mentioned above, there is no currently introductory geochemistry course and this would be a new course that I am developing based on previous content I've experienced at UC Davis and UC Berkeley. The course has the added benefit of incorporating the analytical facilities within the College of Science, each of which I have extensive experience using as part of my research. The course will also allow me to apply the skills learned in the HHMI-AEES program to create and equitable and inclusive upper-level undergraduate and graduate course that combines lecture and analytical work from the ground up.

The new geochemistry course enhances the course offerings within Geology curriculum and the College of Science. There is no comprehensive geochemistry course currently offered in the Geology program, and yet, our undergraduate and graduate students regularly work with geochemical data and instruments as part of their post-graduate employment and M.S. research. Geology is a diverse discipline and the fundamental principles of geochemistry include topics such as, environmental monitoring and remediation, earthquake recurrence intervals, weathering and landslide potential, anthropogenic impacts on the ocean and atmosphere, arc magmatism, and the age and evolution of the Earth. The course would form the basis of new and more advanced geochemistry courses, such as GEOL 497P597P (Stable Isotope Geochemistry) taught by new faculty member Camilo Ponton and could also be cross-listed within the new Marine Science program. In addition, AMSEC is currently considering an initiative to create a new M.S. program and the proposed course could serve as a course within that proposed program.

The course promotes the missions of the Geology department and College of Science by serving the science needs of Washington state and benefits students in their professional and academic careers. The Geology department prides itself on producing majors with a multidisciplinary background and the diverse range of geochemical applications, from environmental impacts to hazard mitigation, are important and timely topics in our state. In addition to learning fundamental geochemical concepts and principles, students will gain valuable hands-on experience with modern geochemical instrumentation, data analysis, and interpretation through the lab exercises. This experience will broaden their knowledge base, increase their skill sets, and enhance their competitiveness in future pursuits after Western.

Expected results or outcomes

Successful summer funding will allow me to create a new geochemistry course that incorporates a series of problem sets and lab exercises as described above. The course will be initially taught every other year and be offered to 20 students at a time. In addition to creating this course content, I will create a learning progression and set of course outcomes that can be shared internally with peers in Geology or other faculty in the College of Science that may use the course a pre-requisite for more advanced courses. The learning progression, problem sets, and labs will also be shared online with the Earth Science community through websites such as Science Education Resource Center (SERC) for others to use and improve upon.