Research Interests

My research interests stem from a desire to characterize and understand chemical 'communications' between earth materials. I am interested in leveraging the information encapsulated in natural samples using an array of geochemical approaches to explore how elements — particularly volatiles (F, Cl, Br, I, H_2O, CO_2, S) — are stored and transferred during geologic processes. Topics of interest include subduction zone metamorphism and exhumation, grain- to regional-scale fluid-rock interactions, mineralogical controls on volatile behavior, and the influence of halogens on metal solubility and transport. Ultimately, I'm interested in exploring geochemical cycling, which I believe is a necessary component to understanding interactions between the solid earth and the hydrosphere, atmosphere, and biosphere. Below is a description of past and current research projects, including collaborators and publications. I close with a discussion of future research directions.

Geochemical cycling of halogens

1. Determination of bulk rock halogen (F, Cl, Br, I) abundances in mafic samples using ion chromatography (IC) and inductively coupled plasma mass spectrometry (ICP-MS) to establish constraints on halogen devolatilization from altered ocean crust (AOC) during prograde subduction zone metamorphism. Comparing the contents of seafloor AOC samples to those of eclogites exhumed from three paleo-subduction settings: Raspas Complex in Ecuador, Cabo Ortegal in Spain, and Zambezi Belt in Zambia. Provides novel data for elements that have not previously been characterized in these lithologies. Results indicate efficient halogen transport through the forearc and arc as well as significant halogen subduction to depths of arc-magma genesis and beyond.

   Collaboration with Dr. Jaime Barnes (UT Austin), Dr. Timm John and Dr. Elis Hoffmann (Free Univ. Berlin, Germany). Two international visits to conduct analytical work with collaborators in Berlin, Germany. Samples provided by Ocean Drilling Program. Beaudoin et al. (pending re-submission) EPSL.

2. This study uses a suite of ophiolite samples from the Western Alps—encompassing peak metamorphic conditions from sub-greenschist to eclogite facies—to study progressive halogen devolatilization from subducted AOC in samples that are petrogenetically related. Unique sample set enables greater resolution of the minerals and textures that influence the devolatilization process.

   Collaboration with Dr. Jaime Barnes (UT Austin). Two summers of fieldwork, Western Alps (France, Italy, Switzerland). Manuscript in prep.

3. Vein transects in eclogites from different exhumed ophiolites (Raspas Complex, Ecuador; Monviso, W. Alps; Tianshan, NW China; Pouébo Eclogite Mélange, New Caledonia) are used to evaluate halogen mobility in high-P environments. Halogens are measured in bulk rock samples with increasing distance from fluid pathways that formed by local devolatilization or external fluid infiltration. The combination of spatial and chemical information allows for unique insights into the movement of halogens deep within subduction zones.

   Collaboration with Dr. Jaime Barnes and Dr. Rudra Chatterjee (UT Austin), Dr. Timm John (Free Univ. Berlin, Germany). Manuscript in prep.

Mineralogy

4. Electron microprobe analyses (EPMA) of exhumed metasedimentary rocks from the Schistes Lustrés and Catalina Schist to identify the mineral phases controlling the Cl budget and measure the Cl concentration across metamorphic grade. Results revealed decreasing concentrations of Cl in the primary mineral host phases, chlorite and phengite, as they underwent devolatilization at increasing peak P-T conditions.
   Collaboration with Dr. Jaime Barnes (UT Austin), Dr. Sarah Penniston-Dorland and Will Hoover (UMD), and Dr. Gray Bebout (Lehigh Univ.). Barnes et al. (2019) Lithos.

5. Measurement of bulk rock F and Cl in high-P eclogites from the Raspas Complex, Ecuador to evaluate the efficacy of different methods (bulk rock analyses via pyrohydrolysis and IC versus in situ measurements via secondary ionization mass spectrometry or SIMS) in attempting to quantify the distribution and abundance of halogens in low concentration samples.
   Collaboration with Ben Urann and Dr. Véronique Le Roux (WHOI). Urann et al. (2020) American Mineralogist.

Exhumation-related fluid-rock interactions

6. Measurement of chlorine stable isotope (δ^{37}Cl) values using gas source isotope ratio mass spectrometry (IRMS) in volatile-rich samples from the Zambezi Belt, Zambia that show evidence of exhumation-related alteration and rehydration. Stable isotopes, halogen abundances, and major and trace element chemistry are used to interpret the source of external fluids with implications for fluid circulation at the slab-mantle interface.
   Collaboration with Dr. Jaime Barnes (UT Austin) and Dr. Timm John (Free Univ. Berlin, Germany). Manuscript in prep.

7. In this outcrop-scale study, a core-to-rim transect which captures the retrograde transition of eclogite to blueschist in a metamorphic block from Jenner, CA is used to explore the physicochemical conditions operating during exhumation of a mafic block. Extensive petrographic observations provide context for whole rock (XRF) and in situ (EPMA) chemical data, which are used to determine that the change in mineralogy from core to rim was due to elemental exchange with an external reservoir, to model the composition of the ultramafic host mélange, and to constrain the P-T conditions of exhumation (via THERMOCALC).
   Collaboration with Dr. Sean Mulcahy at UC Berkeley. Results presented at 2015 GSA Annual Meeting. Honors thesis: Transition of Franciscan eclogite to blueschist in a metamorphic block from Jenner, CA.

Methodological advancement

8. Extensive wet chemistry and empirical testing to develop the materials and procedures necessary for the establishment of a robust ICP-MS method to analyze solutions with low concentrations of Br and I in geologic samples at UT Austin. This will be the first facility in the US with such a capability.
   Collaboration with Dr. Rudra Chatterjee, Dr. Jaime Barnes, and Dr. Danny Stockli (UT Austin).

Future research

The projects outlined below are a selection of potential research directions, all of which are suitable and scalable for undergraduate or graduate student involvement, from sample preparation to publication.

1. Heavy halogens (Br and I) are present at low— but potentially consequential—abundances in mafic rocks following subduction zone devolatilization. The sites (structural or otherwise) that are responsible for hosting these elements in high-P assemblages is presently unknown. Detecting these elements in situ is impossible using typical equipment (SEM and EPMA). Determining mineralogical controls of the Br and I budget could be accomplished by synchrotron radiation micro x-ray fluorescence (SR-μXRF) spectroscopy, which has been demonstrated to be a productive method for imaging the distribution of trace elements in natural samples. If this approach proves fruitful, this non-destructive method could be applied to many other samples, including extraterrestrial materials. *Method requires an external facility, such as the APS at Argonne National Lab; users do not pay for beamtime.*

2. Sediments are an important volatile reservoir that influence the physical and chemical properties of subduction zones. However, due to the great variability in sediment composition, volatile abundances in this reservoir are often broadly generalized. In order to improve models of geochemical cycling, work is needed to systematically characterize the abundance of volatiles in sedimentary and metasedimentary materials. *This work would be complemented by a collaboration with Dr. Sedimentologist.*

3. The transfer of sediment-derived fluids to other lithologies is frequently invoked to explain unusual chemical and isotopic observations. A careful investigation of fluid pathways (veins, fractures, etc.) can be conducted to explore the effects of metasomatism via sediment-derived fluids. *This work would be complemented by a collaboration with Dr. Fluid-Modeler.*

4. Halogens promote metal transport and ore formation by complexing with metals to form metal halides, which are more soluble in geologic fluids. Halogens abundances can be utilized as a tool in resource exploration. Further studies of halogens (particularly Br and I) in skarns and ore deposits will provide insight into how these elements interact with economically important metals in complex geologic settings. *This work would be complemented by a collaboration with Dr. Economic-Geologist.*

5. Bromine is highly effective at destroying stratospheric ozone. Large volcanic eruptions that release Br have been linked by some researchers to observations of subsequent ozone depletion. As the climate warms, other sources of Br may be mobilized, potentially entering the atmosphere. Elevated Br abundances have been reported in gas hydrates in marine settings and in permafrost. Evaluating the size and volatility of these currently inert Br reservoirs may help in forecasting future atmospheric conditions. *This work would be complemented by collaborations with Dr. Mineral Physicist and Dr. Climatologist.*