The subcontinental lithospheric mantle (SCLM) keeps a geochemical memory of its complex tectonic history. It is accessible as mantle xenoliths, which are carried to the surface by basalts and preserve the geochemical imprints of continental crust formation, orogeny, rifting, subduction, and plume activity. It is possible to extract this information using modern analytical techniques, specifically the rhenium-osmium (Re-Os) isotope system is useful to constrain the crust formation ages, which are masked in other isotope systems by later events.

The western Ross Sea area of Antarctica (Figure 1) experienced a long tectonic history, which is preserved in mantle xenoliths erupted in volcanic rocks of the West Antarctic Rift System (WARS). Active volcanoes are currently observed along the western side of the Ross embayment, and suggest present day rifting of the Antarctic continent (Dalziel and Lawver, 2001). The WARS, which separates Marie Byrd Land from the Transantarctic Mountains and the East Antarctic Craton, forms a series of subglacial basins that contain sedimentary rocks from the Cretaceous to Cenozoic and represents one of Earth’s largest rift systems (Cooper et al., 1991; Weaver et al., 1994).

The SCLM as sampled by mantle xenoliths preserves information on the lithospheric history that is not visible in the overlying continental crust. In particular, the Re-Os isotope system can be applied to mantle-derived rocks (mantle xenoliths), such as lherzolites, harzburgites, wehrlites, and websterites as a tracer of melt extraction and thus crust formation (Walker et al. 1989; Shirey and Walker, 1998; van Acken et al., 2008). Melt extraction is thought to be the primary control on Re and Os abundances in mantle rocks (Walker et al. 1989; van Acken et al., 2008). The reason for this is that Re and Os concentrate in trace sulfides and platinum group element alloys. During melting, the highly compatible Os remains in the solid residue, while the moderately incompatible Re is concentrated in the melt fraction. Thus, Re and Os abundances, as well as $^{187}$Os/$^{188}$Os ratios of mantle peridotites are little affected by melt and fluid migration in the mantle (Handler et al. 1997; van Acken et al., 2008) and thus provide a robust tracer for melt depletion and therefore crust formation ages. The interpretations from this project can also be applied to understanding the evolution of other globally distributed rift systems.
Proposed Activity

The Re-Os system proves to be an invaluable tracer of the tectonic history of the SCLM. Although methods for Re-Os analysis are well-established at this point, the Lamont-Doherty Earth Observatory is not yet set up for this analytical method. The Re-Os method involves the digestion of rocks by reacting them with aqua regia (3:1 hydrochloric acid + nitric acid solution) in thick-walled Pyrex tubes (Carius tubes) under high temperature and pressure conditions for approximately 12 hours (Shirey and Walker, 1995). Re and Os are then separated from the rock matrix using a double distillation procedure and subsequent anion exchange chromatography. While other digestion methods exist, the Carius tube digestion achieves more complete dissolution, allowing for higher retention of Os, and thus resulting in higher reproducibility during sample analysis (Shirey and Walker, 1995). The reason for the complex separation of Re and Os from the sample is to avoid isobaric interferences, which are overlapping and indistinguishable signals of isotopes with the same atomic mass (particularly \(^{187}\text{Re}\) with \(^{187}\text{Os}\)).

I propose to visit the Department of Terrestrial Magnetism (DTM) at the Carnegie Institution of Washington from June 6-21, 2011 to learn the Carius tube digestion method under the guidance of Dr. Steve Shirey. Together with Richard Walker, Dr. Shirey established the procedure and published it in the Journal of Analytical Chemistry (Shirey and Walker, 1995). Due to the complex nature of this procedure, it requires supervised training at a well-established laboratory. Dr. Shirey has agreed to host me at DTM and train me in the analytical method as well as sample analysis by Thermal Ionization Mass Spectrometry (TIMS) on a Thermo Scientific Triton (mass spectrometer). I have arranged to digest and analyze ~10 samples for Re and Os isotopes over the course of 16 days.

Itinerary

June 6: Arrive at Union Station, Washington, D.C.
June 7: Arrive at Department of Terrestrial Magnetism at the Carnegie Institution of Washington. Meet with Dr. Shirey and colleagues and discuss samples.
June 8: Preparation of samples and materials needed for analytical procedure
June 9: Training in procedure—digestion of 10 samples
June 10: Training in procedure—digestion of 10 samples (cont.)
June 11-12: (lab closed on weekend—meet with scientists and plan for next step)
June 13: Training in procedure—double distillation
June 14: Training in procedure—double distillation (cont)
June 15: Training in procedure—anion exchange chromatography
June 16: Training in procedure—anion exchange chromatography (cont)
June 17: Training in instrumentation—analyze samples by TIMS
June 18-19: (lab closed on weekend—meet with scientists and discuss data interpretation)
June 20: Training in instrumentation—analyze samples by TIMS
June 21: Final training and analysis of remaining samples. Meeting with Dr. Shirey to address any questions. Depart from DTM in the evening.
**Expected Outcomes**

The Chevron Student Initiative Fund will provide me with the opportunity to learn from one of the world leaders in Re-Os chemistry. I will also be trained on the Triton Thermal Ionization Mass Spectrometer (TIMS), instrumentation used to analyze Re-Os isotopes. DTM unites scientists from several disciplines to answer important questions about the physical processes on Earth and the universe. The Chevron Student Initiative Fund will allow me to interact with the scientists at DTM and build lasting collaborations early in my graduate career. The data obtained during this trip will provide me with a preliminary data set and a better understanding of the SCLM in the formation of the West Antarctic Rift System.

The geochemical laboratories at Lamont Doherty Earth Observatory (LDEO) are not set-up for the Re-Os chemical procedure or analysis of Re-Os isotopes by TIMS. I plan to set up the Re-Os chemistry at LDEO based on the experience gathered during my training at DTM. Dr. Bärbel Hönisch maintains the Thermo Scientific Triton TIMS at LDEO, which is currently set up for boron isotope analysis only. The advantage of TIMS is that it has a wide range of applications, including the high precision measurements of Re and Os. While the Re-Os analysis is not set-up on the Triton, Dr. Hönisch has agreed to allow me to set up the run script for Re-Os measurements on the TIMS, and maintain it for future analyses.

The primary outcome of this proposal is to establish the analytical method for low-blank analysis of Re and Os at LDEO. By establishing this procedure at LDEO, it would allow me to work on a larger sample set in a shorter period of time, without the need to travel to another laboratory and related schedule and travel constraints. Prior to beginning my graduate studies in DEES, I worked as a laboratory technician at Montclair State University, where I established the iron co-precipitation procedure for subsequent Nd analysis, as well as introducing sediment-leaching techniques. I worked as a research assistant at LDEO and trained both graduate and undergraduate students in cation exchange chromatography and Nd column chemistry. I also worked with students from the summer intern program to set up the calibration method for K-Ar isotope dilutions and analytical measurements on small sample volume sediments. During the Fall 2010 semester, I was a graduate teaching assistant for Modern Analytical Methods in Geochemistry and I currently manage the lab in Comer 318. I am confident in my ability to set up Re-Os method here at LDEO and feel that it will be a great opportunity to further demonstrate my analytical skills. Furthermore, this would grant other graduate students at LDEO access to this invaluable technique.

Although I am a first-year graduate student, I was admitted with a Master’s degree and will take my orals examination already Spring 2012. This significantly limits the amount of time I have to conduct research prior to the orals examination. Being trained at DTM will allow acquisition of data that otherwise I might not be able to collect prior to my orals examination. I would be able to use Re-Os data in conjunction with trace element data and Sr-Nd-Hf isotope data that I will collect using established analytical methods at LDEO to tell a more complete story about the geochemical and tectonic history of the West Antarctic Rift System, which will greatly enrich my Ph.D. dissertation. In addition, the analytical training at DTM proposed here will provide the basis for me setting up the Re-Os procedure at LDEO, which will represent an important
part of my Ph.D. in demonstrating my analytical capabilities. We plan to present the results from this training and analysis at an international conference in 2012.

Bibliography


## Chevron Student Initiative Fund Proposed Budget

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**Total Budget** $996.91

### Budget details:

1. **$19.00 round trip transportation between Pearl River Station, NY and Newark Penn Station via NJ Transit**
   a. June 6, 2011: Depart from Pearl River—Arrive at Newark Penn Station
   b. June 21, 2011: Depart from Newark Penn Station—Arrive at Pearl River

2. **$98.00 round trip transportation between Newark Penn Station and Union Station via Amtrak**
   a. June 6, 2011: Depart from Newark Penn Station—Arrive at Union Station, Washington, D.C.
   b. June 21, 2011: Depart from Union Station, Washington, D.C.—Arrive at Newark Penn Station

3. **$50.00 round trip transportation between Union Station and Carnegie Institution via Yellow Cab taxi (15.8 miles round trip)**

4. **$400 total for lodging**
   a. $25/day for 16 days
   b. Room accommodations arranged by host (Dr. Steven Shirey)

5. **$400 total for food**
   a. $25/day for 16 days
   b. Estimate of food from previous trips