

GEOS 496-596 “Hand-on Geochronology”, Department of Geosciences, University of Arizona, Spring of 2025

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Description of the course

Much of Earth and planetary sciences relies on chronometric use of radioactive decay and growth of naturally occurring nuclides to understand the timing of geological events and rates of processes. This course will introduce undergraduate and graduate students to the practical aspects of geochronology at the Arizona LaserChron Center (ALC), providing training, so students can become independent in conducting their own geochronologic analyses in the lab. We will focus on the application of U-Pb geochronometers in phases such as zircon, monazite and apatite, and Lu-Hf dating of garnet, coupled with petrography and thermodynamic modeling for petrologic interpretations. Students will receive two rock samples from the Adirondack Mountains in New York State, which they will prepare to conduct measurements using the mass spectrometers in the ALC labs. They will also conduct petrographic analyses with thin-sections, electron microprobe geochemistry, and thermodynamic modeling using the software PERPLE_X, and analyze and interpret geochronological data using Matlab-based codes and Excel sheets at the computer lab of de Dept. of Geosciences.

Journal of classes

1st class: Jan 14th 2025. This class was the introduction to the course and I took the lead of the class. They were 16 students and we decided to split the class in two groups, since they were going to have two samples to work with, one to each group. The two groups also would have their class in different days, established as Monday and Tuesday from 9:30 to 11 AM. They were 16 students, 8 to each group. Both groups were going to work with metamorphic rocks from the Adirondack Mountains, New York State, the Monday group had a metasedimentary rock, and the Tuesday group had a metagabbro. Mark Pecha, the Arizona Laserchron Center (ALC) manager, showed the students the ALC forms for safety in the labs, which students had to fill before starting the course.

At the second half of the time, I gave a lecture about Precambrian Geology in the USA to introduce them to their study region during the semester. It took 20-30 minutes and there was discussion time in the end which took 5-10 minutes, students engaged after the first 2 questions, when more discussion started to happen. The whole class took 1h. The preparation of the lecture took around 4 h.

Total hours worked: 5 h

2nd class Jan 21st and 22nd 2025. This class was a lab safety training in the ALC with Mark Pecha. It took 1.5 h each day, I followed them both days. I also worked on the syllabus that week and had a meeting with Mauricio to discuss the syllabus, it took 2h.

Total hours worked: 5h

3rd class Jan 27th and 28th 2025. This class was dedicated to rock crushing, one of the ALC staff prepared the samples showing each step of the process to the students. They put the samples to dry in the lab hood. I followed only the Tuesday group. The same week I prepared their samples for thin section preparation, it took me 2h. I also worked on my teaching plan and had an FLC, it took 2h.

Total hours worked: 5 h

4th class Jan 3rd and 4th 2025. I started this class showing them the hand samples and doing an activity of mineral recognition and how to give a name to the rock. I asked petrological characteristics of the main minerals of the rock and they were participative. At the end they were capable to give a

name to their rocks, for example, gneiss and metagabbro. After that, we went to the ALC lab and they were trained to work with the Frantz, a magnetic separator of minerals. One of the ALC staff also showed them how the heavy liquids separation works. Students worked in the Frantz during the week, and I helped with sample preparation, it took me 3.5 h plus the class time.

Total hours: 5 h

5th class Feb 10th and 11th 2025. This class was very active, we started with a 30 min lecture about minerals to pick for geochronology analyses, given by Mark Pecha. Students were participative with the questions and activities. After that, we went to the Raman spectrometer lab with Michelle (ALC Postdoc) and she explained how it works. Students organized with her to do analyses in the Raman to check their minerals composition after the magnetic separation that they did with the Frantz. After that, we went to the picking lab and Mark and Mauricio shown how to pick specific crystals like zircon, apatite, monazite, rutile, and titanite. Their work this week was focused on picking these crystals and checking their composition in the Raman.

I sent the sample's powder that I prepared the week before for X-Ray Fluorescence analysis at Hamilton College (external lab). I also worked on the thin sections description.

Total hours worked: 5 h

6th class Feb 17th and 18th 2025. In this class we checked the picked crystals and mount standards on it to have them ready for the mass spectrometers. The Monday group was able to have zircon, apatite, monazite, and rutile. The Tuesday group was able to pick apatite, was challenging to pick zircon, and it took them one additional week sieving and picking the sample again to get zircon from the very fine portion of the rock. In class, we also looked at the mineralogy of the rock under the microscope, doing a review of the petrography. I used some time off class to show them the thin sections under the microscope.

We propose them to write an abstract to GeoDaze, a conference organized by the Geosciences Department at the University of Arizona. Each group had a responsible for the abstract.

Total hours worked: 7 h

7th class Feb 24 and 25th 2025. This class was in the scanning electron microscope, where a ALC staff showed them how the SEM works and some images of zircon after SEM and cathodoluminescence pictures were taken. Mauricio and I also gave them a lecture about the Geology of the Adirondacks to discuss the geological context related with their samples. They were able to already have an idea of the metamorphic conditions that rocks experienced, since they have already analyzed the thin sections.

During the week Mauricio and I met with students to work on their abstracts for GeoDaze.

Total hours worked: 5h

8th class March 3rd and 4th 2025: This class was the great day in the ALC mass spectrometers for geochronology! Mauricio showed them the two mass spectrometers, the Neoma and the Neptune, showing their parts and explaining how it works. After that, students picked the crystals to be dated using the cathodoluminescence images taken with the SEM. Some of them stayed with me during the analysis. This took two full days, one in the Neoma and one in the Neptune, followed by ALC staff.

Total hours worked: 8h

Spring Break March 10th week: I performed microprobe analysis on their samples to the thermobarometry part of the project. Some students could join although it was not required.

Total hours worked: 5h

March 17th and 18th 2025: We worked in their posters for GeoDaze. We decided to use only zircon U-Pb data from the mass spectrometry analysis, since the data are easier to process compared with apatite and monazite U-Pb ages. Mauricio showed them how to use the software IsoplotR to plot geochronological data in useful diagrams for interpretation. We also discussed figures and interpretations for the poster.

Total hours worked: 5h

March 27th and 28th 2025: GeoDaze week, no class on Monday and Tuesday but they presented their poster on Wednesday 27th. It was a great opportunity to students to engage with the class and learn about geochronology, tectonics and the geology of US. They had discussion with other students and researchers and for some of them was their first participation in a scientific conference.

Total hours worked: 4h

March 31st and April 1st 2025: After all the hard work to prepare and analyze their samples for geochronology, we had time to work on their data processing and interpretation using computer software. Mauricio taught them how to use AgeCalc using MATLAB and Excel, and he also explained them the theory behind U-Pb dating. This class was focused on zircon U-Pb

Total hours worked: 3h

April 7th and 8th 2025: This class was similar to the last one, focusing on the AgeCalc software and its capabilities. We also plotted the data reduced with AgeCalc using IsoplotR.

Total hours worked: 3h

April 14th and 15th 2025: This class was similar to last class but focused on monazite U-Pb data reduction and plotting the data into diagrams.

Total hours worked: 3h

April 21th and 22th 2025: This class was similar to last class but focused on apatite U-Pb data reduction and plotting the data into diagrams.

Total hours worked: 3h

April 28th and 29th 2025: This class was focused on the concept of diffusion. Mauricio gave a lecture about it and gave them three exercises using Excel spreadsheets to calculate the closure temperature of different geochronological systems. In the future, I would spend more time on this since was not an easy concept. Would be good to resolve the exercise with them in class and then applying it to the age calculation.

Total hours worked: 3h

May 5th and 6th 2025: I leaded this class showing them how to interpret geochemical data from the X-ray fluorescence and electron microprobe. I taught the basics of thermodynamic modeling and then taught them how to use the software Perple_X to produce phase diagrams and estimate the peak temperature and pressure of metamorphism of their rocks. Although we had to go fast through some concepts, were able to generate the diagrams, and using the tutorial that I made and provided to them, they could finish their phase diagrams to their final presentation.

Total hours worked: 6h

Final exam May 12th 2025: Students presented their final project in their respective groups, they had 15 minutes to show all the work they did, their results and interpretation in the regional geological context. They did a good job on putting all together and bringing the questions that they have about it, and we could discuss for 1 hour. They even went beyond U-Pb geochronology, and showed other geochronology studies for the study region and discussing their results in that context.

As part of their final examination, they will also have to produce an individual report of what they did in class and they can choose if they want to focus on a specific part of it.

Total hours worked: 4h

Total hours worked during the course: 84h.

My summary and conclusions about the course:

This was an amazing teaching experience since students really engaged with the proposed research and Mauricio was a very good mentor, giving me space to teach and introduce concepts and methods into the course. For example, I led the petrography and thermodynamic modeling part of the course, but also had support from Patricia Kang, a postdoc in the ALC and from the ALC staff. I also added to the course teaching tectonic and geodynamic processes, and mentoring students to write abstracts and produce a poster to the GeoDaze 2025 conference, which was the first scientific event to many of them. I followed all the steps of sample preparation and analyses, and helped many students to pick crystals, look at thin-sections, conduct analyses in the mass spectrometers and the electron microprobe, and later to analyze and interpret their newly generated data. Although proposing a research project to undergrads and grad students requires a lot of work and commitment, I would recommend using this approach for teaching, since students feel more connected with the study object and thus, learn more. It's also an advantage to the instructors, since students' efforts can be incorporated into further research, and the discussions help us to understand our own research. Thus, both sides gain from this experience and I am really delighted to have participated in the CIRTl Postdoc Pathway Program.

Veleda Muller, May 16 2025.