GEOS 290A: Isotope Geology

MWF 12:30-1:30
JSC 223

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What this course is about

This course is about isotopes and their use in the geosciences. Isotopes are one of the most powerful tools in the geoscientists toolkit. Isotopic analysis is used to determine the age and petrogenesis of rocks, as a tracer for fluids in the crust, as a means to study climate change in the past and present, and much more. Ever more advanced means of measuring isotopic ratios have made isotopic systems once considered beyond the limit of instrumental sensitivity more feasible, and present-day methods make it possible to use almost every naturally-occurring isotopic system to study the origin and evolution of rocks, minerals, fluids, and gases. With so many new methods available, isotopes have become ubiquitous in the geoscience literature. In the latest issue of *Geology*, the flagship journal of the Geological Society of America, 8 of 22 new articles present isotope-based research.

The focus of this class is mainly on the applications of isotopes in geoscience. The basic physical principles governing each isotopic system we study will be covered as well, but the purpose of the course is not to make you all experts in quantum mechanics. Rather, we will focus our attention mainly on the isotopic methods used by geoscience professionals to study the Earth.

Goals of this course

The primary goal of this course is to provide you with enough fluency in isotope geology to be able to understand isotope-based studies in the geologic literature. For those of you that go on to do geoscience research in graduate school or industry, this course will provide a basis for you to understand how isotopes can aid you in your research pursuits and a solid footing upon which to understand research projects that involve isotopes. The main questions we will address are:

1) What are isotopes, and how are they measured?
2) What are radiogenic isotopes and how are they used in the geosciences?
3) What are stable isotopes and how are they used in the geosciences?

Course outline

This course meets for three hours a week, during which time we will discuss various aspects of isotopes in geosciences and work through problem sets. Because there is no required textbook (but see the following page for some recommended resources), the entirety of the course content will be delivered to you during the scheduled class period. I will periodically assign readings from the general literature or textbooks on reserve in the library to bolster the material given in class. However, it is very important that you attend every class session and take good notes, or you will have nothing to study for the exams!

There will be homework assigned for each topic that is geared towards quantitative problem-solving using the theory discussed in class. Exams (two midterms and a final) will test your ability to interpret isotopic data as it is presented in the literature, and your understanding of the theory that you will work through in the homework.

Your grade will be based on:

Homework: 20%
Midterms (two): 40%
Final exam (comprehensive): 40%

See the last page of the syllabus for the topics we will cover and the order in which we will cover them.

Course materials

There is no required textbook for this course. However, I do recommend several textbooks for use as general reference. These are listed below. Some of these titles will be on reserve in the Prevo library.

Faure, G. and Mensing, T. M., 2005, *Isotopes, Principles and Applications (3rd Edition)*. Wiley, 897 p.

This is an updated edition of the classic *Principles of Isotope Geology* (the first textbook available on the subject, now out of print). This is the isotope geologist's bible, and it focuses mainly on applications of isotopic systems in geology. The third edition contains information on nearly every isotopic method currently used in the geosciences. Of all the textbooks in print today, this one most closely follows the content of our course.

Available in hardcover for $125 from amazon.com. The original, *Principles of Isotope Geology* (1977) is on reserve in Prevo.

White, W. M., 2014, *Isotope Geochemistry*. Wiley, 477 p.

This is an entirely new textbook that was just released in print January, 2015. Although I haven't had time to review it thoroughly yet, it is highly quantitative and contains a lot of detail on the theoretical aspects of isotope geochemistry. It is recommended only for students who have had calculus and have an interest in delving more deeply into how isotopic systems work, or are planning to use isotope geochemistry and require a good reference manual.

Available in paperback for $66 from amazon.com

Allégre, C. J., and Sutcliffe, C., 2008, *Isotope Geology*. Cambridge University Press, 512 p.

A very easy to read, basic review of radiogenic and stable isotope systems. Excellent introductory section on mass spectrometry.

Available in hardcover for $90 from amazon.com. On reserve in Prevo.

Two additional titles focus only on stable or radiogenic isotope geology:

Sharp, Z., 2006, *Principles of Stable Isotope Geochemistry*. Prentice Hall, 360 p.

A recent textbook covering principles and applications of **stable isotopes** in the geosciences. Does not cover radiometric dating or principles of radiogenic isotopes. For that topic, see the next book.

Available in paperback for $125 from amazon.com

Dickin, A., 2005, *Radiogenic Isotope Geology*. Cambridge University Press, 512 p.

Covers principles and applications of **radiogenic isotopes** in the geosciences.

Available in paperback for $99 from amazon.com. On reserve in Prevo.

Attendance policy:

If you miss a class due to illness, etc., you are responsible for obtaining the notes, lab assignments, homework, etc. from someone else in the class.

GEOS 290A Topics

The following is a list of topics we will cover in this class. Exam dates will be announced a week in advance.

Part 1: Fundamentals of isotopes and their measurement

- Origin, basic physics, and classification of atoms and nuclei: masses and binding energies, elemental abundances, nuclides, isotopes, isotones, and isobars, nucleosynthesis, and radioactive decay.
- Isotopic measurement techniques: mass spectrometry, types of mass spectrometers, calibration, measurement, and standards.

Part 2: Radiogenic isotope geology

- Radioactive decay rates and the decay equation.
- Radiogenic decay systems and applications:
    - U-Th-Pb geochronology and provenance
    - K-Ar, Ar/Ar geochronology
    - Rb-Sr geochronology
    - Sm-Nd geochronology and tracer studies
    - Lu-Hf geochronology and tracer studies
    - Radiocarbon dating
    - Cosmogenic nuclides
    - Low-temperature systems: AFTA, U-Th-He

Part 3: Stable isotope geology

- Stable isotope theory: fractionation, notation, equilibrium and kinetic effects.
- Stable isotope systems: oxygen, carbon, hydrogen, sulfur.
- Low-temperature applications: tracer studies, climate change, atmosphere and biosphere effects.
- High-temperature applications: geothermometry, magmatic and hydrothermal systems.

Final Exam: Friday, December 19, 8:30 AM