

## Earth Sciences 9506a. Isotope Geochemistry in Earth and Environmental Sciences

Fall Term 2013 (Lectures are combined with Earth Sciences 4431a)

When: Monday, Wednesday, Friday, 11:30 to 12:20 pm,  
Where: University College, Room 142  
Instructor: Dr. Fred J. Longstaffe, 1023 BGS (Biological and Geological Sciences)  
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Office hours: by appointment

Teaching Assistant: tba

Prerequisites: Some undergraduate experience in Chemistry or Geochemistry  
Anti-requisite: Earth Sciences 4431a or 431a

Grading:

Mid-term test:	25%
Final examination:	35%
Graduate Project:	20%
Problem sets (7):	20%

Important dates:

1. Mid-term test: Friday, **October 25, 2013** (during regular class time)
2. Graduate project due: Friday, **November 15, 2013**
3. Refer to the lecture timetable for due dates of problem sets
4. Final examination date will be set by the Registrar's office and will be held at the same time as Earth Sciences 4431a

Examination dates are firm and make-up examinations will not be permitted. Late assignments will suffer a 5% reduction per day on the final grade for the first 5 days. Assignments submitted more than 5 days late will not be accepted.

Text Book: Faure G. and Mensing T.M. (2005) *Isotopes: Principles and Applications*. John Wiley and Sons Inc., 897 p.

You can buy this book at the UWO Bookstore or through Amazon.ca. This book is also on hold for short-term loan in the Taylor Library. I have listed the book as required because you will need to gain access to it one way or another.

There are short readings associated with most lectures and you are expected to read this material.

Other materials for this course will be placed, as required, on-line on the OWL system: <https://owl.uwo.ca/portal>

Illness and Other Circumstances: If you are unable to meet a course requirement due to illness or other serious circumstances, you must provide valid medical or other supporting documentation to the Dean's office as soon as possible and contact your instructor immediately. It is the student's responsibility to make alternative arrangements with their instructor once the accommodation has been approved and the instructor has been informed. In the event of a missed final examination, a "Recommendation of Special Examination" form must be obtained from the Dean's Office immediately. For further information please see: [http://www.uwo.ca/univsec/handbook/appeals/accommodation\\_medical.pdf](http://www.uwo.ca/univsec/handbook/appeals/accommodation_medical.pdf)

A UWO Student Medical Certificate (SMC) is required where a student is seeking academic accommodation. This documentation should be obtained at the time of the initial consultation with the physician or walk-in clinic. An SMC can be downloaded under the Medical Documentation heading of the following web site:  
<https://studentservices.uwo.ca/secure/index.cfm>.

Accessibility Statement: Please contact the course instructor if you require material in an alternate format or if you require any other arrangements to make this course more accessible to you. You may also wish to contact Services for Students with Disabilities (SSD) at 661-2111 x.82147 for any specific question regarding an accommodation.

Plagiarism: Plagiarism is a serious academic offence. The UWO Senate Academic Handbook defines plagiarism as "The act of appropriating the literary composition of another, or parts or passages of his writings, or the ideas or language of the same, and passing them off as the product of one's own mind." Students must write their essays and assignments in their own words. Whenever students take an idea, or a passage from another author, they must acknowledge their debt both by using quotation marks where appropriate and by proper referencing such as citations. For more information see Scholastic Offence Policy in the Western Academic Calendar. Students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence, at the following web site: [http://www.uwo.ca/univsec/handbook/appeals/scholastic\\_discipline\\_undergrad.pdf](http://www.uwo.ca/univsec/handbook/appeals/scholastic_discipline_undergrad.pdf)

All required papers may be subject to submission for textual similarity review to the commercial plagiarism detection software under license to the University for the detection of plagiarism. All papers submitted will be included as source documents in the reference database for the purpose of detecting plagiarism of papers subsequently submitted to the system. Use of the service is subject to the licensing agreement, currently between The University of Western Ontario and Turnitin.com (<http://www.turnitin.com>).

Electronic devices: Scientific calculators are mandatory for all examinations. No other electronic devices will be permitted.

Support Services:

Registrarial Services <http://www.registrar.uwo.ca/>  
Student Support Center: <http://www.sdc.uwo.ca/>

Guidelines for Graduate Project: This project will require you to assess an isotopic data set and provide an interpretation. The data and guidelines on how to begin will be provided to you.

Course Outline: This outline is a guide only. Isotope Science is a dynamic tool that is applied to scientific research in many different fields. Course content may change depending on feedback from the class and current topics. If you have interest in a subject not covered here, please contact the instructor.

### *Part A – Stable Isotopes*

#### **1. Introduction**

Importance to geological studies, isotopes of interest and some general principles, the atom, chart of the nuclides and isotopes, atomic mass units and atomic weight, binding energy, nuclear stability, cosmic abundance of the elements, the history of stable isotope geochemistry, definitions (the  $\delta$ -value,  $\alpha$ ,  $10^3 \ln \alpha$ ,  $\Delta$ -value), standards, method of study, extraction techniques, mass spectrometry, laboratory tour.

#### **2. Stable isotopes in the atmosphere and hydrosphere**

Equilibrium fractionation of isotopes, kinetic processes, the meteoric water line, Rayleigh distillation, oxygen and hydrogen isotopes in rain, snow and ice, the oceans (evaporation, ice cap effects, pore waters in oceanic sediments), ground water, soil water, geothermal waters, formation waters in sedimentary basins, paleothermometry in the oceans and on land, the isotopic composition of the oceans through time.

#### **3. Stable isotope variations in igneous rocks**

Introduction, oxygen reservoirs (water, sedimentary rocks, the mantle and derivative rock types), mineral ordering, fractional crystallization, the oxygen-isotope geochemistry of granitoid rocks (normal  $^{18}\text{O}$ , low- $^{18}\text{O}$  and meteoric water interaction, high  $^{18}\text{O}$  rocks and the role of sediments, isotopic exchange between granitic rocks and their country rocks), oxygen-isotope geothermometry in igneous rocks, meteorites, mass independent fractionation.

#### **4. Stable isotope variations in weathering and diagenetic processes**

Submarine weathering, oxygen- and hydrogen-isotopes in soil clays and chemical weathering, carbonates and patinas, diagenesis (sandstone) and the Western Canada Sedimentary Basin

#### **5. Carbon- and sulphur-isotope studies of organic matter, fossil fuels and related materials**

Introduction to carbon isotopes, carbon in modern biosphere (photosynthesis) and in soils, fossil fuels, and carbonates, study of diet and migration, atmospheric  $\text{CO}_2$ , carbon in the lithosphere. Introduction to sulphur isotopes, biogenic fractionation, sulphur in recent sediments, hydrocarbons, coal, igneous and sedimentary rock, ore deposits and the environment.

### *Part B – Radioactive and Radiogenic Isotopes*

#### **1. Radioactive decay**

Introduction, decay mechanisms (beta, positron, electron capture, alpha), fission, rates of radioactive decay, half life, decay series and secular equilibrium, applications of natural radioactivity and units of radioactivity

#### **2. An introduction to isotopic dating methods and radiogenic isotopes as tracers of geological processes**

Introduction, K-Ar, Rb-Sr, Sm-Nd, U-Th-Pb (concordia, discordia, zircons, isochrons), extinct radionuclides, fission tracks, cosmogenic nuclides and  $^{14}\text{C}$  dating, heterogeneity of the Earth's mantle, Nd and Sr isotope compositions of the ocean.

## Useful reference materials:

- Attendorn H.G. and Bowen R.N.C. (1987) *Radioactive and Stable Isotope Geology*. Chapman and Hall, London. QE501.4.N9 B69
- Barrie A. and Prosser S.J. (1996) Automated analysis of light-element stable isotopes by isotope ratio mass spectrometry. In: *Mass Spectrometry of Soils* (eds: T.W. Boutton and S. Yamasaki). Marcel Dekker Inc. New York, p. 1-46. S593.M4415
- Boutton T.W. and Yamasaki S. (eds.) (1996) *Mass Spectrometry of Soils*. Marcel Dekker Inc, New York. S593.M4415
- Clark I. and Fritz P. (1997) *Environmental Isotopes in Hydrogeology*. CRC Press, Boca Raton. ISBN 1-56670-249-6
- Coleman D.C. and Fry B. (eds.) (1991) *Carbon Isotope Techniques*. Academic Press, San Diego. QH 324.3.C37
- Dicken A.P. (1995) *Radiogenic Isotope Geology*. Cambridge University Press. QE501.4.N9 D53
- Faure G. (1986) *Principles of Isotope Geology*. John Wiley and Sons, New York.
- Faure G. and Mensing T.M. (2005) *Isotopes. Principles and Applications*, 3<sup>rd</sup> Edition. John Wiley and Sons, New York. ISBN 0-471-38437-2
- Fry B. (2006) *Stable Isotope Ecology*. Springer, New York. ISBN-10 0-387-30513-0
- Hall A. (1996) *Igneous Petrology*. Longman Group Limited, Essex. QE461.H256
- Heaman L. and Ludden J.N. (eds.) (1991) *Applications of Radiogenic Isotope Systems to Problems in Geology*. Mineralogical Association of Canada Short Course 19, Toronto.
- Hobson K.A. and Wassenaar L.I. (eds.) (2008) *Tracking Animal Migration with Stable Isotopes*. Elsevier, Amsterdam. ISBN 978-0-12-373867-7
- Hoefs J (2004) *Stable Isotope Geochemistry*, 5<sup>th</sup> Edition. Springer, Berlin. QE515.H67
- Johnson C.M., Beard B.L. and Albarède, F. (2004) *Geochemistry of Non-Traditional Stable Isotopes*. *Reviews in Mineralogy*, v. 55. ISBN 093995067-7
- Kendall C. and McDonnell, J.J. (eds.) (1998) *Isotope Tracers in Catchment Hydrology*. Elsevier, Amsterdam. ISBN 0-444-81546-5
- Koch P. L., Fogel M. L. and Tuross N. (1994) Tracing the diets of fossil animals using stable isotopes. In: Lajtha K. and Michener R.H. editors (1994) *Stable Isotopes in Ecology and Environmental Science*. Blackwell Scientific Publishing, p. 63-93. QH541.15.S68 L35
- Knowles R. and Blackburn T.H. (eds.) (1993) *Nitrogen Isotope Techniques*. Academic Press, Inc. San Diego. QH324.35.N1 N57
- Kyser T.K. (ed.) (1987) *Stable Isotope Geochemistry of Low Temperature Fluids*. Mineralogical Association of Canada Short Course 13, Saskatoon.
- Lajtha K. and Michener R.H. (eds.) (1994) *Stable Isotopes in Ecology and Environmental Science*. Blackwell Scientific Publishing. QH541.15.S68 L35

- Lewis C.L.E. and Knell S.J. (eds.) (2001) *The Age of the Earth: From 4004 BC to AD 2002*. The Geological Society of London. QE508.A33
- Longstaffe F.J. (ed.) (1981) *Clays and the Resource Geologist*. Mineralogical Association of Canada Short Course 7, Calgary. QE471.3.C55
- Longstaffe F.J. (1987) Stable isotope studies of diagenetic processes. In: *Stable Isotope Geochemistry of Low Temperature Fluids* (ed. T.K. Kyser) Mineralogical Association of Canada 13, p 187-257. Montreal QE501.4.N9 S725.
- Longstaffe F.J. (1989) Stable isotopes as tracers in clastic diagenesis. In: *Burial Diagenesis* (ed. I. E. Hutcheon). Mineralogical Association of Canada Short Course 15, p. 201-277. Montreal.
- Longstaffe F.J. (2000) Chapter 6. An introduction to stable oxygen and hydrogen isotopes and their use as fluid tracers in sedimentary systems. In: *Fluids and Basin Evolution* (ed. T.K. Kyser). Mineralogical Association of Canada Short Course Series, v. 28, p. 115-162.
- Mazor E. (1991) *Applied Chemical and Isotopic Groundwater Hydrology*. Open University Press. ISBN 0-335-15212-0
- Mitchener R. and Lajtha K. (eds.) (2007) *Stable Isotopes in Ecology and Environmental Science*, 2<sup>nd</sup> Edition. Blackwell Publishing, Malden. ISBN-13 978-1-4051-2680-9
- Mellon F.A., Startin J.R. and Self R. (2000) *Mass Spectrometry of Natural Substances in Foods*. Royal Society of Chemistry. TX 547.M45
- Mook W.G. (2006) *Introduction to Isotope Hydrology*. Taylor & Francis, London. ISBN 10 0-415-38197-5
- Ohkouchi N., Tayasu I. and Koba K. (eds.) *Earth, Life, and Isotopes*. Kyoto University Press. ISBN978-4-87698-960-7
- Sharp Z. (2007) *Principles of Stable Isotope Geochemistry*. Pearson Prentice Hall, New York. ISBN-13 978-0-13-009139-0
- Valley J.W. and Cole D.R. (eds.) (2001) *Stable Isotope Geochemistry*. Mineralogical Society of America, *Reviews in Mineralogy and Geochemistry* 43. QE501.4.N9 S724
- West J.B., Bowen G.J., Dawson T.E. and Tu K.P. (eds.) (2010) *Isoscapes – Understanding Movement, Pattern, and Processes on Earth through Isotope Mapping*. Springer. ISBN 978-90-481-3356-6