Public Viewing Syllabus for Geology 9506 *(v. 1.0, July 10, 2025)*

1. Course Information

Geology 9506. Stable Isotope Geochemistry in Earth & Environmental Sciences
(offered concurrently with Earth Sciences 4431a)

- Fall Term
- In person

List of Prerequisites

- Some undergraduate or graduate experience in bioarchaeology, chemistry, geochemistry and/or biology, or permission of the Instructor.

Anti-requisite
- Earth Sciences 4431a

2. Instructor Information

- Instructor: Fred J Longstaffe, Dept. Earth Sciences
- Graduate Teaching Assistant: To be announced, *to be announced*
- Students must use their Western (@uwo.ca) email addresses when contacting their instructors.
- Weekly office hours with Graduate Teaching Assistant:
  To be announced; format virtual
  To be announced; format in person
  When known, details will be provided via the OWL Brightspace course site.
- office hours with Instructor – always welcome but by appointment

General information about enrolling in graduate courses can be found at:

https://grad.uwo.ca/academics/courses/index.html

3. Course Syllabus, Schedule, Delivery Mode

Lay Summary: You will learn that you are what you eat – isotopically. You will learn that your hair and teeth retain isotopic signals of where you have lived. And you will learn that it is not all about you. Minerals have a history too, and you will learn how to decode that history using stable isotopes, in terms of temperatures and fluids involved in mineral formation. You will learn what sorts of water-

rock-organic interaction might make you rich and at what cost to Earth. Stable isotopes hold the key to understanding much of past climate change, paleo-ecological shifts and extinctions. You will learn to think like an ***Isotopist***. Your life will never be the same thereafter.

Technical Summary: Atoms of many elements come in different varieties known as isotopes. Isotopes of an atom have the same number of protons and electrons, but a different number of neutrons. Stable isotopes of an atom do not decay to form another element. Because of the difference in mass arising from different numbers of neutrons, stable isotopes of a given element behave ("fractionate") in slightly different ways during reactions such as (i) evaporation of water, (ii) carbon dioxide fixation during photosynthesis, (iii) crystallization of a magma, and (iv) transfer of a donut's isotopic signature to your fingernails and hair. This course addresses the principles governing the fractionation of stable isotopes, and focuses on how the stable isotopes of oxygen, hydrogen, carbon, nitrogen and sulphur allow us to trace interactions within the atmosphere-hydrosphere-biosphere-lithosphere Earth System.

Learning Outcomes

Upon successful completion of this course students will be able to:

1. Use the oxygen- and hydrogen-isotope compositions of water to determine its source and the hydrological processes that have shaped the water's isotopic composition, as evaluated through assignments, tests and written examination
2. Identify the sources (mantle, crust) that have contributed to magma generation, and recognize the nature of rock-water interaction that may have affected an igneous rock after its crystallization, as evaluated through assignments, a written test and a written examination
3. Calculate the stable isotope fractionation factor between two phases (e.g., mineral and water), use these data to establish whether the system is in equilibrium, and for equilibrium systems, determine the temperature at which equilibration occurred, as evaluated through assignments, a written test and a written examination
4. Use the oxygen- and hydrogen-isotope composition of clay minerals to determine conditions of weathering and hydrothermal alteration, and interpret these results within the larger framework of diagenesis, ore mineralization and / or climate change over Earth history, as evaluated through assignments, a written test and a written examination
5. Identify photosynthetic pathways in vegetation using stable carbon-isotope compositions, recognize land use changes based on stable carbon-isotope compositions of organic matter, and determine the diet and trophic level of animals based on the stable carbon- and nitrogen-isotope compositions of their tissues, as evaluated through a written test and a written examination
6. Use the stable carbon- and oxygen-isotope compositions of Earth's biosphere, atmosphere and hydrosphere to identify changes in Earth's carbon and water cycles at geological and Anthropocene time-scales, as evaluated through a written test and a written examination
7. Devise methods using light stable isotope signatures to trace Earth System interactions across the lithosphere, pedosphere, hydrosphere, biosphere and atmosphere continuum, as evaluated through a written, data-based major project

This vast amount of space is reserved for $Dy^{2}Hr^{16}O^{32}Sp^{1}Here$

(First one to solve the riddle and tell Fred by e-mail gets 1 bonus mark)

Course Outline

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

1. **Introduction**
   Importance to earth and environmental sciences, isotopes of interest, some general principles, the atom, chart of the nuclides, atomic mass units, atomic weight, binding energy, nuclear stability, abundance of the elements in the solar system, brief history of stable isotope geochemistry, definitions (δ, α, $10^3 \ln\alpha$, Δ), standards, introduction to analytical methods and instruments (extraction techniques, mass spectrometry), virtual laboratory tour.

2. **Stable isotopes in the atmosphere and hydrosphere**
   Equilibrium fractionation of isotopes, kinetic processes, O and H isotopes in water and water vapour, Rayleigh distillation, Global Meteoric Water Line, kinetic isotope fractionation and *d*-excess, evaporation line, regional effects (latitude, altitude, continentality, temperature, precipitation amount), Kuhn, in-cloud processes and O and H isotopes of precipitation, shallow ground water, atmospheric oxygen and carbon dioxide, juvenile water, geothermal water, rock-water ratio, oceanic pore water, formation water, brines (SW Ontario examples), ocean water (salinity, evaporation, dilution, ice-cap effects, ocean currents, climatic effects), snow and ice, marine paleoclimate reconstruction (ice cores, marine foraminifera), terrestrial and lacustrine paleoenvironmental reconstruction (speleothems, mammalian teeth and bones, ostracodes, diatoms), plant phytoliths, tree rings.

3. **Stable isotopes in igneous rocks**
   Introduction to igneous rocks, oxygen reservoirs (water, sediments, mantle and derivative rock types), mineral ordering, fractional crystallization, O-isotope geochemistry of granitoid rocks (normal- ^{18}O, low-^{18}O, meteoric water interaction, high-^{18}O, role of sediments, isotopic exchange with country rocks), O-isotope geothermometry, high temperature concordancy, retrograde isotopic exchange and disequilibrium, Pegmatite Paradise; meteorites, mass independent fractionation.

4. **Stable isotopes in sedimentary rocks, weathering and diagenesis**
   Chemical sediments (carbonate, chert), clastic sediments, submarine weathering (halmyrolysis), O-isotope composition of the ocean through time and its significance, clay mineral structures, controls on clay mineral isotopic compositions during weathering and diagenesis, clay isotope geothermometry, O- and H-isotope variation in soil and weathering clays.

5. **Stable carbon and nitrogen isotopes in organic matter**
   Introduction to stable C isotopes on Earth, photosynthesis (C_3, C_4, CAM and aquatic plants), C-isotope fractionation during photosynthesis (diffusive, enzymatic), fractionation during organic synthesis, C-isotope behaviour during vegetation shifts and climate change, isotopic alteration of soil organic matter (oxidation, microbial), humic substances, tracking carbon storage in soils (Maya examples), N-isotope variations in air, soil, plants and animals, diet and paleodiet (collagen,

structural carbonate in bioapatite, keratin), C- and N- isotope trophic effects, food webs, N-isotope baselines, *are you what you eat*?

6. **Stable carbon isotopes in the carbon cycle**
   Carbon cycle (long- versus short-term), carbon reservoirs (δ and fluxes), long-term carbon cycle, carbonates, equilibrium C-isotope fractionation, vital effects, coal, petroleum, natural gas, biogenic methane, tracing hydrocarbon leaks, short-term carbon cycle (atmospheric CO_2, atmosphere-biosphere-hydrosphere transfer, ice-cores, biological pump, ocean productivity), Phanerozoic C-isotope secular variations (atmospheric oxygen, extinction events, Strangelove Ocean, PETM), Earth C-isotope budget.

7. **Sulphur isotopes**
   Introduction to S isotopes, fractionation in abiotic and biotic systems, Rayleigh distillation, Recent sediments, ocean water, secular variation, atmospheric sulphur, petroleum, coal, S isotopes as a tracer, mass independent S-isotope fractionation, S isotopes in ore deposits, crystal chemistry and bond-strength controls on S isotopic fractionation, speciation effects on sulphur isotopic compositions ($f[O_2]$ and pH), comparison with C-isotope system.

8. **Thinking like an Isotopist**

Key Sessional Dates:
First Class: Friday, September 5, 2025
Reading Week (no classes): Monday, November 3, 2025, to Sunday, November 9, 2025
Last class: Monday, December 8, 2025

Contingency plan for an in-person class pivoting to 100% online learning
Although the intent is for this course to be delivered in person, should any university-declared emergency require some or all of the course to be delivered online, either synchronously or asynchronously, the course will adapt accordingly. The grading scheme will **not** change. Any assessments affected will be conducted online as determined by the course instructor.

4. Course Materials

- Text Book: Sharp, Z. (2nd Edition) Principles of Stable Isotope Geochemistry, Electronic Edition.

  *You can obtain a copy at **no cost** from:* csi.unm.edu *under the web site's publications tab.*

  There are assigned readings from this textbook associated with most lectures.

- All course material will be posted to OWL Brightspace: http://owl.uwo.ca .

- Students are responsible for checking the course OWL Brightspace site (http://owl.uwo.ca) on a regular basis for news and updates. This is the primary method by which information will be disseminated to all students in the class.

• If students need assistance with the course OWL Brightspace site, they can seek support on the OWL Brightspace Help page. Alternatively, they can contact the Western Technology Services Helpdesk. They can be contacted by phone at 519-661-3800 or ext. 83800.

Technical Requirements *(only in case of shift to on-line status)*
• Computer and stable internet connection
• If possible, computer with working microphone and/or webcam
• Patience

5. Methods of Evaluation

The overall course grade will be calculated as listed below:

Assignments (5)	20 %
Midterm Test	30 %
Graduate Project	15 %
Final Examination	35 %

• Assignments and their due dates will be delivered and received via OWL Brightspace. Normally one week is allowed to complete each problem set. For a few assignments, two weeks are allowed.

• *Topics to be included on the Mid-term Test:* All material up to the lecture before the Mid-term Test.

• The Mid-term Test will occur during regular class time on **Wednesday, October 29, 2025**. In case of a shift back to 'on-line' learning, the Mid-term Test will still be administered during the regularly scheduled class time. Those details would follow on the course's OWL Brightspace site.

• The Graduate Project will require you to assess an isotopic data set, provide an interpretation and summarize your findings in a short report. The data and guidelines on how to begin will be posted on OWL Brightspace no later than **Monday, October 6, 2025.**

• The Graduate Project is due by **4:30 pm, Monday, November 10, 2025**, and will be received via OWL Brightspace.

• *Topics to be included on the Final Examination:* Entire course but with emphasis on material covered after the Mid-term Test.

• The final examination date and location will be scheduled by the Registrar's Office during the normal December examination period. In case of a shift back to 'on-line' learning, the final examination will be administered in a 'take-home' format. Those details would follow on the course's OWL Brightspace site.

6. Student Absences

Students who experience an extenuating circumstance (illness, injury or other extenuating circumstance) sufficiently significant to temporarily render them unable to meet academic requirements may submit a request for academic consideration. Please contact your home department's Academic Co-ordinator for further details.

Students are required to contact their instructors within 24 hours of the end of the absence period covered.

Individual instructors are not permitted to receive documentation directly from a student, whether in support of an application for consideration on medical grounds, or for other reasons.

• There are no 'make-up' options for missed Assignments (each worth 4 %). After 48 hours from the deadline, 10 % per day or fraction of a day is deducted for late assignments, and assignments received more than 120 hours late will not be accepted. In case of extenuating circumstances, students should contact the instructor.

• The Mid-term Test date is firm and make-up Mid-term Tests are not offered. If your home Department has approved your circumstances (through the Academic Co-ordinator), then the value of the Mid-term Test will be shifted to the Final Examination. Please ensure that the course instructor is informed of this approval.

• 10 % per day or fraction of a day is deducted for a Graduate Project Report that is more that 48 hours late. A Graduate Project Report received more than 120 hours late will not be accepted. If your home department has approved your circumstances (through the Academic Co-ordinator) that caused an up to 120-hour delay in submission of your Graduate Project Report, then the late penalty will be waived. Please ensure that the instructor is informed.

• There are no 'make-up' options for a missed Graduate Project Report. If your Department has approved your circumstances (through the Academic Co-ordinator), then the value of the Graduate Project Report will be shifted to the Final Examination. Please ensure that the instructor is informed of this approval.

If you miss the Final Examination, please contact your home department's Academic Co-ordinator as soon as you are able to do so. The Academic Co-ordinator will assess your eligibility to write the Special Examination (the name given by the University to a makeup Final Examination).

• Special final examinations will be held as mandated by the University, with the details to be provided by the Registrar.

7. Accommodation and Accessibility

7.1 Religious Accommodation

When conflicts with a religious holiday that requires an absence from the University or prohibits certain activities, students should request an accommodation for their absence in writing to the course instructor and/or the Academic Advising office of their Faculty of Registration. This notice should be

made as early as possible but not later than two weeks prior to the writing of the examination (or one week prior to the writing of the test).

Please visit the Diversity Calendars posted on our university's EDID website for the recognized religious holidays:

https://www.edi.uwo.ca.

7.2 Accommodation Policies

Students with disabilities are encouraged to contact Accessible Education, which provides recommendations for accommodation based on medical documentation or psychological and cognitive testing. The policy on Academic Accommodation for Students with Disabilities can be found at:

https://www.uwo.ca/univsec/pdf/academic_policies/appeals/Academic Accommodation_disabilities.pdf.

7.3 Academic Policies

Use of @uwo.ca email: In accordance with policy,

https://www.uwo.ca/univsec/pdf/policies_procedures/section1/mapp113.pdf,

the centrally administered e-mail account provided to students will be considered the individual's official university e-mail address. It is the responsibility of the account holder to ensure that e-mail received from the University at their official university address is attended to in a timely manner.

Requests for Relief (formally known as "appeals")

Policy on Request for Relief from Academic Decision:
https://uwo.ca/univsec//pdf/academic_policies/appeals/requests_for_relief_from_academic_decisions.pdf

Procedures on Request for Relief from Academic Decision (Graduate):
https://uwo.ca/univsec//pdf/academic_policies/appeals/graduate_requests_for_relief_procedure.pdf

7.4 Scholastic Offences

Policy on Scholastic Offences:
https://uwo.ca/univsec//pdf/academic_policies/appeals/scholastic_offences.pdf

Procedures on Scholastic Offences (Graduate):
https://uwo.ca/univsec//pdf/academic_policies/appeals/graduate_scholastic_offence_procedure.pdf

Use of Electronic Devices During Assessments

In courses offered by the Faculty of Science, the possession of unauthorized electronic devices during any in-person assessment (such as tests, midterms, and final examinations) is strictly prohibited. This includes, but is not limited to mobile phones, smart watches, smart glasses, and wireless earbuds or headphones.

Unless explicitly stated otherwise in advance by the instructor, the presence of any such device at your desk, on your person, or within reach during an assessment will be treated as a *scholastic offence*, even if the device is not in use.

Only devices expressly permitted by the instructor (e.g., non-programmable calculators) may be brought into the assessment room. It is your responsibility to review and comply with these expectations.

- **In Geology 9506, non-programmable calculators are permitted in written tests and examinations.**

Use of Generative AI Tools

In Geology 9506, the use of generative AI tools (e.g., ChatGPT, Microsoft Copilot, Google Gemini, or similar platforms) is **not permitted** in the completion of any course assessments, except for the five assignments, where generative AI use is **permitted with limitations**. Those limitations are that the generative AI tool can be used to research responses to assignment questions but must not be used for final writing of answers. Where a generative AI tool has been used to explore responses to questions, this must be clearly state with each response where generative AI was used.

Using such tools for content generation, code writing, problem solving, translation, or summarization—when not explicitly allowed—will be treated as a **scholastic offence**. The general policy is that If the use of generative AI is permitted for a particular assessment, the conditions of use will be specified by the instructor in advance. If no such permission is granted, students must assume that use is prohibited. It is your responsibility to seek clarification before using any AI tools in academic work.

7.5 Support Services

Students who are in emotional/mental distress should refer to Mental Health@Western:

https://uwo.ca/health/

for a complete list of options about how to obtain help.

Western is committed to reducing incidents of gender-based and sexual violence (GBSV) and providing compassionate support to anyone who has gone through these traumatic events. If you have experienced GBSV (either recently or in the past), you will find information about support services for survivors, including emergency contacts at:

https://www.uwo.ca/health/student_support/survivor_support/get-help.html.

To connect with a case manager or set up an appointment, please contact support@uwo.ca.

Learning-skills counsellors at Learning Development and Success (https://learning.uwo.ca) are ready to help you improve your learning skills. They offer presentations on strategies for improving time management, multiple-choice exam preparation/writing, textbook reading, and more. Individual support is offered throughout the Fall/Winter terms in the drop-in Learning Help Centre, and year-round through individual counselling

Western University is committed to a thriving campus as we deliver our courses in the mixed model of both virtual and face-to-face formats. We encourage you to check out the Digital Student Experience website to manage your academics and well-being: https://www.uwo.ca/se/digital/ .

Western's Laboratory for Stable Isotope Science (LSIS)