Yukon University	School of Science
	GEOL 211 **Geochemistry**
	Winter 2023 **3 Credits**
Course Outline	

INSTRUCTOR: Dr. Joel Cubley
OFFICE LOCATION: M107 (CNIM Building)
E-MAIL: jcubley@yukonu.ca
PHONE: (867) 456-8605

COURSE DATES: January 4 – April 10, 2024
COURSE TIMES: Tuesday/Thursday 9:00 – 10:30 am (lecture); Monday 1:00 – 4:00 pm (lab)

COURSE DESCRIPTION

This course examines the chemical processes characteristic of specific geological settings, with an emphasis placed on the processes governing elemental differentiation, migration, and distribution. Discussion topics include high and low temperature fluid-rock interaction, aqueous geochemistry, stable and radiogenic isotopes, thermodynamics and kinetics, biogeochemistry, and solid-Earth geochemistry. Students will be introduced to common analytical techniques for determining rock, mineral, soil, and water compositions.

Laboratory exercises will focus on developing competencies in the collection, presentation and analysis of geochemical data. Investigations will utilize analytical equipment housed at the College including the atomic absorption (AA), Fourier-transform infrared (FTIR) and x-ray fluorescence (XRF) spectrometers. Students will gain an ability to independently assess and critique geochemical results.

COURSE REQUIREMENTS

Prerequisites: Successful completion of GEOL 200 (Mineralogy), CHEM 110 (The Structure of Matter), and CHEM 111 (Chemical Energetics and Dynamics); or by permission of the instructor. Prior completion or concurrent enrolment in GEOG 101 and/or GEOG 102 (Physical Geography I, II) is advantageous but not required.

EQUIVALENCY OR TRANSFERABILITY

Receiving institutions determine course transferability. Find further information at: https://www.yukonu.ca/admissions/transfer-credit

LEARNING OUTCOMES

Upon successful completion of the course, students will be able to:

- Describe the geochemical evolution of the solar system and Earth and apply chemical concepts to predict the outcome of geologic and tectonic processes.
- Describe the principles behind common analytical techniques; gather and interpret their own geochemical data using the appropriate instrumentation and data processing techniques.
- Plan and carry out appropriate mathematical strategies for solving applied geochemical problems.
- Apply radiogenic isotope systems to fingerprint reservoir compositions and determine the absolute and/or cooling ages of rocks and minerals; use stable isotopes to reconstruct past climatic conditions.
- Use their understanding of thermodynamics, kinetics, and aqueous geochemistry to predict mineral and fluid-rock reactions for a geochemical system and given environmental conditions.
- Manipulate major oxide and trace element geochemical data to interpret the petrogenesis of igneous rocks.

COURSE FORMAT

Weekly breakdown of instructional hours

This course consists of two 90-minute lectures and one ~3-hour lab period per week. It is expected that this course will require 3-5 hours/week of homework and additional reading. It is important to note that the time required will vary by individual.

Delivery format

All components are offered in a face-to-face format. The schedule included in this course outline details the major topics covered and when those topics will be presented throughout the course. Lab exercises will be conducted in classroom, laboratory and field settings. The time required for certain lab exercises will vary depending on the complexity of the exercise and the data processing involved. Whereas these exercises will be on average 3 hours in length, expect variation in time requirements. Advanced notice will be provided at least one week prior if an exercise will conclude later than 4 pm.

Students are strongly encouraged to attend all lectures and lab classes. Hands-on exercises conducted during class time cannot be completed after-hours unless prior permission from the instructor is obtained.

EVALUATION

Weekly Lab Assignments	30% (3% each)
Final Assay Report	10%
Theory Problem Sets	10% (5% each)
Midterm Exam	20%
Final Exam	30%
Total	100%

Assignments

The main assessments for this course are weekly lab assignments. Lab sections are intended to give students the opportunity to apply their geochemistry knowledge to real-world, applied problems in a range of geoscience disciplines. These activities will utilize Yukon examples and case studies wherever appropriate. Lab assignments will be due *at the start of the next lab class* unless otherwise indicated by the instructor. Successful completion of these lab assignments is critical for understanding and reinforcing course material. Several of these lab assignments will be returned with feedback for incorporation into a final assay report.

Two theory assignments will be assigned by the instructor during the course and focus on geochemical data analysis and calculations. These are intended to directly reinforce concepts covered in lecture.
Late theory or laboratory assignments will be graded based on the following scheme: a deduction of 10% per business day up until a total deduction of 50% is reached. Following that, assignments will no longer be accepted and will receive a mark of zero.

Exams

There will be two lecture exams in this course: a midterm lecture exam delivered during class time approximately halfway through the course, and a final lecture exam administered during the final exam period.

Competencies in hands-on lab work will be assessed throughout the course and are not targeted during a formal lab exam.

COURSE WITHDRAWAL INFORMATION

Refer to the YukonU website for important dates.

TEXTBOOKS & LEARNING MATERIALS

There is one required textbook for this course, as well as supplementary textbooks that will be utilized on a limited basis throughout the course. All texts are available on reserve at the Yukon University Library.

Required textbook
Albarède, F. 2009. Geochemistry: an introduction. 2nd ed. Cambridge, UK: Cambridge University Press. 355 p.

Supplementary textbooks
Faure, G. 1998. Principles and applications of geochemistry. 2nd ed. Upper Saddle River, NJ: Prentice Hall, Inc. 600 p.

Rollinson, H.R., and Pease, V. 2021. Using geochemical data: evaluation, presentation, interpretation. Cambridge, UK: Cambridge University Press. 346 p.

White, W.M. 2013. Geochemistry. New Jersey: Wiley-Blackwell. 668 p.

ACADEMIC INTEGRITY

Students are expected to contribute toward a positive and supportive environment and are required to conduct themselves in a responsible manner. Academic misconduct includes all forms of academic dishonesty such as cheating, plagiarism, fabrication, fraud, deceit, using the work of others without their permission, aiding other students in committing academic offences, misrepresenting academic assignments prepared by others as one's own, or any other forms of academic dishonesty including falsification of any information on any Yukon University document.

Please refer to Academic Regulations & Procedures for further details about academic standing and student rights and responsibilities.

ACCESSIBILITY AND ACADEMIC ACCOMMODATION

Yukon University is committed to providing a positive, supportive, and barrier-free academic environment for all its students. Students experiencing barriers to full participation due to a visible or hidden disability (including hearing, vision, mobility, learning disability, mental health, chronic or temporary medical condition), should contact Accessibility Services for resources or to arrange academic accommodations: access@yukonu.ca.

TOPIC OUTLINE

Module	Topic	Accompanying Readings from Albarède
1	**Properties of elements:** Review of the periodic table, chemical bonding, states of matter, geochemical classifications, elemental reservoirs, radioactivity.	Ch. 1 (5-24)
2	**Earth in the solar system:** formation of elements and nucleosynthesis, formation of the solar system, condensation of planetary material, composition of Earth and its ongoing differentiation, origin of seawater.	Ch. 11 (248-287)
3	**Mass conservation and elemental fractionation:** conservation of mass, elemental fractionation, films and interfaces, distillation processes.	Ch. 2 (25-44)
4	**Solid-Earth geochemistry:** distribution of trace elements between coexisting phases, factors governing the value of partition coefficients, geochemical variability of magmas, mantle and crustal melting, magmatism at specific tectonic sites, mantle convection and geochemical reservoirs, growth of continental crust.	Ch. 10 (218-247)
5	**Stable isotopes:** principles of fractionation in hydrological and biological systems, delta notation; isotope geothermometry, stable isotopes in hydrothermal systems and ore deposits, stable isotopes in the mantle and magmatic systems, paleoclimatology.	Ch. 3 (45-70)
6	**Radiogenic isotopes and geochronology:** decay systems and their applications, cosmogenic and fossil isotopes, isochrons, radiogenic tracers.	Ch. 4 (70-100)
7	**Element transport and reactions:** reaction kinetics and reaction rates, relationship between kinetics and thermodynamics, advection, adsorption, diffusion, concept of closure temperature, kinetics of dissolution and leaching.	Ch. 5 (101-119)
8	**Geochemical systems:** single-reservoir dynamics, interaction of multiple reservoirs, mixing and stirring.	Ch. 6 (120-137)
9	**Aquatic chemistry:** acid-base reactions, speciation and complexation in solutions, electrolyte chemistry, dissolution and precipitation reactions, clays and clay properties, interaction of mineral surfaces with solutions, the carbonate system, marine chemistry.	Ch. 7 (138-167)

10	**Biogeochemistry:** the geological record, organic compounds and their nomenclature, important biochemical processes and the chemical properties of organic molecules, biominerals and biomarkers, biological controls on the ocean-atmosphere system, carbon cycle and climate.	Ch. 8 (168-183)
11	**Environmental applications of geochemistry:** characterization of metal leaching and acid rock drainage (MLARD) potential, mine water treatment, water monitoring.	Background resources distributed on Moodle.
12	**Methods for geochemical analysis:** atomic absorption spectroscopy, X-ray fluorescence spectroscopy, electron microprobe analysis (wavelength and energy-dispersive spectroscopy), mass spectrometry (ICP-MS, TIMS), Raman spectroscopy.	Background resources distributed on Moodle.

LABORATORY TOPICS

Week	Topic
1	**Sample preparation practices:** field trip to ALS Minerals preparation facility in Whitehorse (*no assessment but participation required)*.
2	**In-house sample preparation:** laboratory safety procedures; cutting, crushing and grinding of student samples; loss-on-ignition (LOI) analyses with ferrous-ferric iron corrections.
3	**Aqua regia digestions and assay preparation**: dissolution of powdered, ignited ores for base metal assay analysis using industry-standard hot digestion methods.
4	**Atomic absorption spectrometry:** determination of base metal concentrations in powdered ores using flame atomic absorption spectrometry (FAAS); construction of calibration curves using synthesized standards.
5	**Whole rock fusion analysis**: preparation of samples using whole rock fusion technique; chemical analysis of glass beads using x-ray fluorescence (XRF) spectrometry. Creation of calibration curves from standard suites to improve accuracy of XRF results. Comparison of XRF results on powdered, pelletized, and fused bead samples.
6	**Stable isotopes:** exercise to identify patterns of marine oxygen isotope change from benthic forams; relating these changes to patterns of ice-volume change in the Quaternary.
7	**Radiogenic isotopes**: use of Rb-Sr isotope data and whole-rock isochrons to calculate isochron ages and make inferences about magma source regions.
8	**Tectonic discrimination analysis**: use of major and trace element whole-rock data to classify igneous rocks and make informed interpretations about tectonic (eruptive) setting. Includes construction of ternary plots, spider diagrams using ioGAS geochemical software.
9	**Chemical fractionation in magmas:** use of rare earth elements (REEs) to model silicate melting and crystallization. Determination of distribution coefficients and elemental concentrations in solid and liquid phases; creation of numerical models for fractional crystallization and equilibrium modal melting.
10	**Aqueous geochemistry and water-rock interactions:** applications of aqueous geochemistry in passive mine water treatment; sample collection and preparation of sample columns, analysis of water samples using flame atomic absorption spectrometry (FAAS).
11	**Metal Leaching and Acid Rock Drainage (MLARD):** characterizing the potential for metal leaching and acid rock drainage in aqueous and/or solid samples.