Geol 575 – Organic Geochemistry – Spring 2020

Department of Earth Sciences, USC

Synopsis: Advanced course on the fundamentals and frontiers of organic geochemistry. Topics include biomarker and isotope geochemical approaches to reconstructing past marine and terrestrial environmental change.

Approach: This course provides an advanced discussion of the fundamentals and emerging breakthroughs in organic geochemistry. We explore the analytical frontiers of organic and isotope biogeochemistry as applied to paleoclimatology, paleoceanography and geobiology. We consider marine and terrestrial biomarkers from "source" organism to sedimentary "sink". We discuss organic geochemical insights into paleoenvironmental change, current research questions and method developments. Class structure includes lectures, literature based discussion, problem sets and individual research projects. Students will develop a research proposal on an organic geochemical theme with relevance to their thesis.

Instructor: **Prof. Sarah Feakins**, feakins@usc.edu Office: ZHS 223F, x07168
Office Hours: when office door is open or by appointment

Class time: 2 ½ hours once a week, tbd in ZHS 200

Course credits: 3 units

Grading:
20% Homework Assignments
20% Midterm Examination (take home, open book)
20% Participation in class tutorial discussions
20% Final research presentation
20% Final Examination (closed book)

Reading:
Killops & Killops: An Introduction to Organic Geochemistry
(2nd Edition) (2005) Blackwell Publishing. *Available FREE online!*
https://sites.google.com/site/killopsiog/

Chemical Biomarkers in Aquatic Ecosystems Bianchi & Canuel
Princeton University Press (February 28, 2011) *Optional.*

Journal readings *to be read for discussion in class, including instructor-assigned and student-chosen articles related to research interests.*

Recommended preparation: CHEM 105, 322, GEOL 107, 150, 412 or similar.

Learning Objectives:

- Students will be able to structurally identify key features of organic molecules calculate isotopic fractionations between substrate and product using excel.
- Students will gain a broad theoretical knowledge of how to calibrate and apply organic geochemical proxies to a range of paleoenvironmental reconstructions.
- Students will be able to articulate the source and fate of organic molecules across geological time, and their significance in the geological record.
- Students will learn how organic geochemistry skills translate to industry careers.

Week 1 **Introduction to Organic Geochemistry**
Welcome to the course and introductions. Origins of the discipline, disciplinary journals, reading tips. Nomenclature, structure of natural products. Principals of solvent extraction, chromatography, derivatization, preparatory methods. *Reading practical and introductory material.*
Assignment #1 learning the language of OG, names & structures, due-date.

Week 2 **Laboratory safety.** Complete GLS safety training. Familiarity with SOPs for organic solvents NEW: Developing your laboratory safety awareness for your research.

Locating organic geochemistry archives: 1) Familiarize yourself with IODP marine core drilling and ICDP continental drilling and other means of acquiring sediments for organic geochemistry research. 2) Identify a project of interest to "drill" into for your term project. Research your chosen core using results from the IODP initial proceedings and subsequent publications.
Assignment #2 lab safety & identifying archives, due-date.

Week 3 **Life, biomolecules and the geologic record**
Bulk organic matter, compound class and individual biomarkers. Consideration of source organisms, diagnostic and refractory compounds.
Reading: Chapter 2, Killops & Killops, Bianchi and Canuel useful.

Week 4 **Plant wax: production, fate and interpretation**
Prof. Feakins specializes in the study of plant leaf waxes. These waxy molecules have important functions for plants, are some of the most resilient compounds made by plants, and leave their legacy in geological archives that can be used for vegetation and climate reconstructions.
Reading: various Feakins lab and other publications from 2016-2017
Analytical methods: Introduction to GC-MS/FID spectral analysis, compound identification, quantification. Tour of lab instrumentation at USC.
Assignment #3 Practicum: extract alkanes from a plant leaf, run a column, obtain training on an instrument, run a sample, interpret your results, due next in class.

Week 5 **Carbon isotope biogeochemistry**
Carbon isotopic fractionation in lipid synthesis in aquatic and terrestrial systems. C_3, C_4 and CAM plants. pCO_2 reconstructions. Suess effect.
Reading: Diefendorf & Freimuth, 2017; Killops and Killops p4, 17, 234-245.
Analytical Methods: introduction to GC-IRMS. Basic training in Isodat software and view Thermo instrumentation at USC. *Reading: Sessions 2006.*
Assignment #4 calculating C and H isotopic fractionations, propagating errors, due-date.

Week 6 **Hydrogen isotope biogeochemistry**
We will begin with how and why hydrogen isotope fractionation in the water cycle record useful aspects of climate, including observational data, climate models and interpretations. We will then move onto hydrogen isotope biogeochemistry in plants and their organic molecules, studying how those hydrological signals are recorded and modified in biological and geological systems. We will consider plant water uptake, water regulation through stomata, biosynthetic fractionations during lipid synthesis, and questions of stability during preservation. We will also consider hydrogen isotopes in heterotrophs and in microbes and plants in a range of

environments including across salinity gradients, and the use for proxies of past salinity. *Reading: Sachse et al.,2012; Zhang & Sessions, 2009, student choices. How to report isotopic data, Reading: Coplen et al., 2008*

Week 7 Presidents Day no class meeting this week, research proposal writing
Develop an OG LOI: Develop a short 'letter of intent style proposal for OG centered research on your chosen IODP, ICDP, or other drill core. *What is the overarching problem that this would address? Identify a specific research hypothesis or question that is tractable. What organic geochemical methods would be appropriate, what instrumentation, what time period to span, & what sampling resolution?* **Assignment #4 writing: your research proposal LOI due-date.**

Week 8 **Molecular paleoceanography**
An overview of organic geochemical approaches to paleoceanography. Proxy development from isolation of biomarkers, attribution to source organisms, culture experiments, sediment trap and coretop calibrations. Highlights from organic geochemical insights into past ocean conditions. Organic geochemical proxies covered will include sea surface temperature proxies based on alkenones from algae and membrane lipids from archaea, as well as newer proxies including diols, the novel sea ice proxy IP25, pCO_2 proxies.
Reading: Eglinton & Eglinton 2008, and select 2015-2018 papers student choice.

Week 9 **Terrestrial organic geochemistry.**
Paleosols, lakes, even caves contain organic molecules. What archives, what proxies? Calibrations. Concerns. Useful complimentary information? We will survey, bulk and compound specific approaches, in addition to leaf wax, we will consider lignin, soil microbial lipids and the altitudinal, temperature and hydrological information they contain. *Reading: calibration & application student choices.*

Midterm examination (take home, open book) due-date**.**

Spring Break, no class

Week 11 **Time & the age of organic matter**
Dating overview; methods of age control; radiocarbon bulk & compound specific; age of organic carbon in the modern environment. *Reading: Ingalls & Pearson, 2005, Pearson & Eglinton 2000, Galy & Eglinton, 2011.*

Week 12 **Production, transport, storage, preservation/degradation of organic matter.**
Understanding the geological context of organic matter. How can we reconstruct production from preservation? What determines selective preservation of components, what aspects of geologic context matter?
Reading: Killops & Killops Chapter 3 p89-116 (also 4)

Week 13 **The ORGANIC carbon cycle**
In this tutorial we will discuss at major organic carbon perturbations of the carbon cycle, often ignored in carbonate-based models. We will evaluate terrestrial inputs of carbon into the oceans, massive deposits of organic carbon, and major changes in the production and decomposition of organic matter across long geological time, across glacial interglacial cycles and on into the Anthropocene. *Reading: Killops & Killops p43-67, Bianchi, 2011, and student choices depending on timescales of interest.*

Week 14 **Fire in terrestrial ecosystems.**
Wildfires are on the rise with climate change. In this tutorial, we will explore ignition, fuel, ecosystem function; proxies and future outlook. *Reading: Randerson, et al. 2011; Masiello, 2004, Yunker 2011 Meyers-Pigg et al.,2017, Santin et al. 2015 or others depending on student interests.*

Week 15 **Industry Careers.** Conventional/unconventional oil, fracking and future fuel. Various conventional/unconventional fuels, represent lucrative employment and R&D opportunities for organic geochemistry graduates. *Reading: tbd*
Assignment #5: write an industry-ready resume

Week 16 **Final research project presentations, peer-review & panel**
Students deliver a presentation on their individual project on an organic geochemical theme with relevance to the topics covered in this class and their thesis research. Students will participate in a full peer-review and panel evaluation process. In so doing they will learn, from their own evaluations and from evaluating others, how to develop stronger proposals and will develop understanding of the peer review process. Final evaluation will be conducted by the professor (just as would be done by the program officer).

TBD **Final examination.** (Closed book). Date determined per exam schedule.

Late Policy: Late assignments and make-up examinations will be permitted with valid academic excuse and prior agreement of the instructor.

Who is this class for? Students who want to develop a professional working knowledge of organic geochemistry sufficient to begin graduate research in organic geochemistry, including training on working safely in a research laboratory, develop research questions and proposals for academic research and guidance to position themselves well for postdoctoral research and/or teaching and/or industry careers. Past participants have included students from Earth Science, Chemistry and Biology. Students have continued on to do research in the Feakins lab, to seek funding from extra mural sources for organic geochemistry, and have moved on into postdoctoral research, faculty positions and most recently as a research scientist at Beyond Meat. Guest speakers from industry and seminars can be a part of the course if interest exists.

Grading rubric

A	Clear and compelling, identifies important scientific problem or research question. Well-articulated, structured, and referenced. Data and examples effectively support argument.
A-	Mostly as above, but some flaws
B (+)[-]	(Lots of) information but limitations in organization, [substantial] missing elements.
C_	Passable effort
D	Unsatisfactory/insufficient
F	Fail/no assignment

Statement on Academic Conduct and Support Systems

Academic Conduct:

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in *SCampus* in Part B, Section 11, "Behavior Violating University Standards" policy.usc.edu/scampus-part-b. Other forms of academic dishonesty are equally unacceptable. See additional information in *SCampus* and university policies on scientific misconduct, http://policy.usc.edu/scientific-misconduct.

Support Systems:

Student Counseling Services (SCS) – (213) 740-7711 – 24/7 on call
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention. engemannshc.usc.edu/counseling

National Suicide Prevention Lifeline – 1 (800) 273-8255
Provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week. www.suicidepreventionlifeline.org

Relationship and Sexual Violence Prevention Services (RSVP) – (213) 740-4900 – 24/7 on call
Free and confidential therapy services, workshops, and training for situations related to gender-based harm. engemannshc.usc.edu/rsvp

Sexual Assault Resource Center
For more information about how to get help or help a survivor, rights, reporting options, and additional resources, visit the website: sarc.usc.edu

Office of Equity and Diversity (OED)/Title IX Compliance – (213) 740-5086
Works with faculty, staff, visitors, applicants, and students around issues of protected class. equity.usc.edu

Bias Assessment Response and Support
Incidents of bias, hate crimes and microaggressions need to be reported allowing for appropriate investigation and response. studentaffairs.usc.edu/bias-assessment-response-support

The Office of Disability Services and Programs
Provides certification for students with disabilities and helps arrange relevant accommodations. dsp.usc.edu

Student Support and Advocacy – (213) 821-4710
Assists students and families in resolving complex issues adversely affecting their success as a student EX: personal, financial, and academic. studentaffairs.usc.edu/ssa

Diversity at USC
Information on events, programs and training, the Diversity Task Force (including representatives for each school), chronology, participation, and various resources for students. diversity.usc.edu

USC Emergency Information
Provides safety and other updates, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible. emergency.usc.edu

USC Department of Public Safety – UPC: (213) 740-4321 – HSC: (323) 442-1000 – 24-hour emergency or to report a crime.
Provides overall safety to USC community. dps.usc.edu