EEPS 0240 EARTH: EVOLUTION OF A HABITABLE PLANET

INSTRUCTOR: Dr. Tim Herbert
Office: Geochem 125
Email: Timothy_Herbert@brown.edu

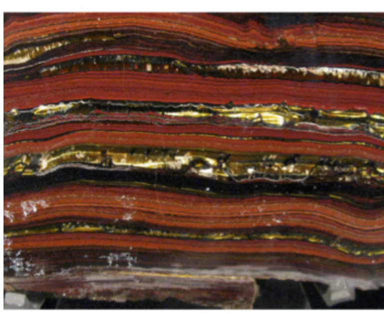
CLASS TIME AND LOCATION: MWF 1-2 pm, MacMillan 115 and Lincoln Field Building 209, labs meet in LF 209
https://brown.zoom.us/j/97361452494

Office hours M,W,F 2-3 p.m., Thurs. 9-10 am or by arrangement
https://brown.zoom.us/j/6425596091

TEACHING ASSISTANTS

Sloane Garelick- *Graduate TA*, Geochem (sloane_garelick@brown.edu)
Margaret Frabell, *Undergraduate TA* (Margaret_frabell@brown.edu)
Emma Perkins *Undergraduate TA* (emma_perkins@brown.edu)
Nuri vanDommelen *Undergraduate TA* (nuri_van_dommelen@brown.edu)
Daniel Wexler *Undergraduate TA* (Daniel_wexler@brown.edu)

COURSE DESCRIPTION:
Why has the Earth, alone of all the planets, been able to support life for at least 3.7 Billion years? What factors have regulated and maintained the Earth's climate near habitable conditions for so long? How do environmental changes of the past inform our understanding of the world we live in today? And how do we know so much about Earth's past? We will examine the principal sources that provide energy to the Earth's surface and modify its composition over time: solar input, carbon and tectonic cycles, and biological processes. Our job as Earth scientists is to identify the processes that shape the Earth's surface environment, assess the characteristic timescales on which they operate, envision how the strengths of different processes could have changed over time to yield different Earth states, and study the Earth's past using a variety of geologic tools.



COURSE OBJECTIVES: By the end of the semester you should be able to:

- Understand Earth systems concepts: feedbacks, response times, dynamic equilibria
- Understand fundamental determinants of Earth's surface temperature on Earth timescales
- Apply geological reasoning to determining the ages and rates of processes recorded in Earth archives such as sediments and the ocean floor
- Communicate your understanding of Earth processes effectively in written form

REQUIRED TEXT: Kump et al. The Earth System. This text contains excellent introductions to Earth systems thinking, the basics of the surface energy budget of the Earth, and the Earth's biogeochemical (especially carbon and oxygen) cycles. We will supplement the book with a number of readings provided to you on the Canvas website.

RECOMMENDED COURSES:_Students are expected to know basic aspects of physical geology: plate tectonics, composition of Earth materials, and major mineral and rock types. Normally, this is satisfied by taking EEPS 0010, 0220, or having an Earth Science background from experiences outside Brown. If you are concerned about your understanding of Earth Science, you can read background material in *Essentials of Geology*, by Stephen Marshak, available on Canvas.

LECTURES: Lectures are designed to highlight the most important topics covered in the textbook and assigned reading. They are not meant to substitute for the work required to read the assigned material! Key figures from lecture will be provided as handouts distributed in class and posted on Canvas. Note that although many of the class concepts will focus on material in the lecture, you are expected to do the readings and understand key terms prior to class. Lectures and class activities will involve students as active participants. I encourage you to ask questions, to participate in small group discussion, and to reflect on in-class problems.

For students attending in-person: I request that you do NOT bring a laptop to class, unless you can speak to me about why one is required for your learning process.

LABS: There will be five labs that emphasize practical aspects of recognizing different types of sedimentary rocks, and the environmental clues left in them. Labs provide a hands-on link to topics discussed in lecture. You must attend one of each of the labs- there will not be make-up labs.

lab #1, Weds. 2/10 & 2/11 Thurs. 2/4 LF 209
lab #2, Weds. 2/17 & 2/18 Thurs. 2/11 LF 209
lab #3, Weds. 3/13 & Thurs. 3/14 LF 209
lab # 4 Weds. 3/31 & Thurs. 4/01 LF 209
lab #5, Weds. 4/07 & Thurs. 4/08 LF 209

PROBLEM SETS: Four to five problem sets will emphasize quantitative application of concepts and equations introduced in class.

WRITTEN ASSIGNMENTS: There will be a short ("Critical Review") and longer writing assignment, based on your reading from the primary scientific literature. You will have a choice of topics, along with suggested readings for each topic (listed in a folder on the Canvas site). Your Critical Review will consist of choosing one article and approaching it as a science journalist- that is, looking for the important questions, context and "big picture" interest of the paper. The longer assignment will ask you to integrate 3-5 readings on the same topic into a more nuanced and deeper look into your topic. We will use the Writing Fellows program for both assignments. Submitting your draft to your Writing Fellow will be **required** as part of submitting your written work for evaluation and grading- you will be asked to submit your commented WF draft on Canvas when you submit your final draft. Suggested writing topics, examples, and guidance are given in the "Critical Review- guidelines" folder in Canvas.

FIELD TRIPS*:* *Depending on University health regulations*, participation in one of two field trips is **mandatory** for students taking the class in person, unless you have a valid excuse such as athletic commitments on both dates and speak to me ahead of time. Field trips allow us to make observations in the natural setting, and tie into concepts covered in class. Our first field trip will be to the southern Rhode Island coast, where we will discuss coastal geological processes and take salt marsh sediment cores that contain a history of five centuries of hurricane activity along our coast. The second trip will go to the Connecticut valley, to observe and measure a sedimentary section recording cyclic changes in an ancient lake basin. Both trips will last for about half the day. Sign- up sheets will be distributed ahead of the trips.

TIME ALLOCATION: Time spent in and out of class for this course is estimated at ~180 hours. Over the 15 weeks of the course, students will spend 3 hours in class each week (~45 hrs), ~10 hours in total in labs, ~6 hours on field trips, and ~1 hour before class reading the assigned text (15 hrs). In addition, I estimate an average of 3 hours for each of four problems sets (12 hrs), 4-5 hours per week going over class notes re-reading the assigned text and articles (60 hrs), 16 hours on the Critical Review and 24 hours on the final term paper (the lengthy time assigned to writing reflects the steps of submitting drafts to Writing Fellows and then re-draft for final submission)**.**

ASSESSMENT: 5% of your grade will be based on lab write-ups, 10% on problem sets, 12.5% for your Critical Review and 22.5% for your final paper, 25% for the mid-term exams, and 25% for the final exam (Note: you cannot pass the course if you fail the final exam). **Late assignments** will incur a 10% deduction per day (i.e. 2 days late = 20% off).

ACCESSIBILITY: Please inform Tim if you have a disability or other conditions that might require some modification of any course procedures. For more information contact Student and Employee Accessibility Services at 401- 863-9588 or SEAS@brown.edu. Also feel free to contact Tim if you need short term academic advice or support, or contact a dean in the Dean of the College office.

DIVERSITY AND INCLUSION: We want students of every background and viewpoint to feel welcomed and respected in our classroom. If you have concerns about how topics are discussed in the course, or how you are respected or included in the course, please share your concerns with Tim. Speak to me after class or email to set up an appointment. If you have a name and/or set of pronouns that differ from those that appear in your official Brown records, please let me know. For further resources related to any aspect of our diverse community, you can also reach out to the Office of Diversity and Inclusion.

ACADEMIC INTEGRITY: I strongly encourage everyone to work collaboratively in your own small study groups and as lab partners, because everyone benefits from such active engagement. However, I expect that you will write all of your homework and lab answers in your own words. If you have any questions ask me, or refer to Brown's Academic and Student Conduct Codes for University policy on academic integrity and penalties for violations.

A FEW RULES TO HELP US ALL LEARN

1) Attendance at all classes is expected. Please let Tim know if you need to miss a class and why.
2) Your behavior (speech, clothing) should be appropriate for a classroom environment. Cell phone use is not permitted during class.
3) Please contact Tim or a TA is you feel any of these rules are being broken or your learning is being impaired.

GE-0240 COURSE SCHEDULE

MODULE 1: EARTH SURFACE PROCESSES

Weeks 1&2 (1/20-1/27) Course Introduction, Earth Systems Thinking
Organization, themes, Daisyworld: Feedbacks in the Earth System
Reading: Kump, Ch. 1-2 (Background Marshak Chapters if you need)

Week 2&3 (1/27-2/5): Earth's Climate
Planetary radiation budgets, circulation of the atmosphere and oceans
Reading: Kump Ch. 3, 4, 5

Assignment: choose topic for critical review by 2/1
Assignment: Problem set #1 due 2/07

Week 4 (2/8-2/12): Shaping the Earth Surface: minerals, erosion, and weathering
Making Sedimentary Rocks: Breakdown of the Earth's surface and erosion rates, Mechanical and Chemical Weathering. River chemistry. Rates of Denudation.
Reading: Langmuir and Broecker Ch.12, Marshak, "Interlude B", Chapter 6.
1st Laboratory Wednesday 2/10, Thursday 2/11, LF 209

Assignment: Draft of critical review to Writing Fellow 2/15

Weeks 5 & 6 (2/15-2/26): How does the Earth maintain a habitable temperature?
The carbon cycle and rock cycles: inputs and outputs of carbon at the Earth's surface, comparison to Mars, Venus
Kump, Ch. 8, Lunine Ch. 15, Lacis Article

2nd Laboratory, Wednesday 2/17, Thursday 2/18, LF 209
Assignment: Problem set #2 due 2/21

1st MIDTERM EXAM: FRIDAY 2/26

MODULE 2: STRANGE EARTHS

Week 7 (3/1-3/5):): Earth: the early years
Formation of the Earth, differentiation, early Earth environments, timescales and age determination
Reading: Kump, Ch. 10, Langmuir & Broecker Ch. 5 & 6

3nd Laboratory, Wednesday 3/03, Thursday 3/04, LF 209

Week 8 (3/8-3/12): When microbes ran the Earth
Metabolic diversity
Reading: Kump Ch. 10, Langmuir & Broecker Ch. 15

Assignment: critical review to professor 3/07 (electronically, w/ WF draft)

Week 9 (3/15): Oxygenating the planet
Reading: Kump, Ch. 11, Langmuir & Broecker Ch. 16

2ND MIDTERM: MARCH 15 (will cover through 3/12)

MODULE 3: ASSEMBLING EARTH AS WE KNOW IT: THE PHANEROZOIC

3rd Laboratory Wednesday 3/03, Thursday 3/04, LF 209

Week 10 (3/22): Putting things in order: stratigraphic tools, Paleozoic life, and Supercontinent cycles
Continental assembly, disassembly, and the carbon cycle. Formation of Pangaea and the Paleozoic, colonization of land, carbon storage and biological evolution, and glaciations revisited
Reading: Stanley 151- 179, Kump, Chapter 13, Stanley Ch.9 [231-255] Stanley, Ch. 16 [452-463], Graham et al. article

Week 11 (3/29): Putting things in order: stratigraphy and the geological time scale
Reading: Stanley 151- 179

Assignment: Problem Set #3 due 3/30, 5 PM

Assignment: Draft of term paper to writing fellows 4/02

FIELD TRIP TO COAST SUNDAY MARCH 28 12:45 p.m., MONDAY MARCH 29 1:30 p.m.

4th Laboratory Wednesday 3/31, Thursday 4/01, LF 209: Sediment cores

Weeks 12 & 13 (4/5-4/12): Climatic evolution of the last 140 Myr: Fire and Ice
Warm Mesozoic & cooling Cenozoic: High CO2 & volcanism. Lowered CO2 & mountain building? Role of continental breakup/oceanic gateways? New biological responses- grasslands, grazers, primates. Arrival of glaciation on Antarctica and northern hemisphere. Cyclic ice ages and the end of the last ice age.

Reading: : Kump, Ch. 14, Stanley, 17 [476-492], Ch. 18 [505-516], Ch. 19 [526-536], 20
Burke et al. (2018)

5th Laboratory Wednesday 4/07, Thursday 4/08, LF 209: Sediment cores

Assignment: Problem Set #4 due 4/11, 5 PM

MODULE 4: THE HUMAN EARTH

Week 13 (4/14,4/16): The Holocene, Last Millennium, and "Anthropocene":
Human domination of local and planetary-scale Earth processes. Future climates. Can we "hack" Earth's future (climate engineering)?

Reading: Kump, Ch. 15, 19; Ruddiman article, Crowley article

FIELD TRIP TO EAST BERLIN SAT. APRIL 10 8:30 AM

RAIN DATE SUNDAY APRIL 11 8:30 AM

FINAL PAPERS SUBMITTED ON CANVAS 4/18 (submit WF draft also)

Final Exam 4/21 take-home

Readings:

Textbook- purchase, or on reserve at the Science Library:
Kump, L.R., J.F. Kasting, and R.G. Crane, The Earth System, Third Edition, Pearson Prentice Hall
Required.

Copies of the following papers/chapters will be distributed via Canvas .pdf files:

Barnosky, A. D., Hadly, E. A., Bascompte, J., Berlow, E. L., Brown, J. H., Fortelius, M., . . . Smith, A. B. (2012). Approaching a state shift in Earth's biosphere. *Nature, 486*(7401), 52-58.

Burke, K. D. , J. W. Williams, M. A. Chandler, A. M. Haywood, D. J. Lunt, and B. L. Otto-Bliesner (2018). Pliocene and Eocene provide best analogs for near-future climates, *Proc. Nat. Acad. Sci*. 115: 13288-13293

Caldeira, K., et al., 2013. The Science of Geoengineering. Annual Reviews of Earth and Planetary Science 41: 231-256.

Crowley, T.J., 2000. Causes of climate change over the past 1000 years. Science 289: 270-277.

Graham, N.J., R. Dudley, N.M. Aguilar, and C. Gans, 1995, Implications of the late Paleozoic oxygen pulse for physiology and evolution, Nature, v. 375: 117-120.

Friedlingstein, P., Meinshausen, M., Arora, V. K., Jones, C. D., Anav, A., Liddicoat, S. K., & Knutti, R. (2014). Uncertainties in CMIP5 Climate Projections due to Carbon Cycle Feedbacks. *Journal of Climate, 27*(2), 511-526. doi:10.1175/jcli-d-12-00579.1

Lacis, A. A., et al. (2010). "Atmospheric CO_2: Principal Control Knob Governing Earth's Temperature." Science **330**(6002): 356-359.

Ruddiman, W.F., 2003. The anthropogenic greenhouse era began thousands of years ago. Climatic Change 61: 261-293.

Zalasiewicz, J., et al. (2011), Stratigraphy of the Anthropocene, *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *369*(1938), 1036-1055.

Book Chapters

Langmuir, C.H., and W.Broecker, 2012, How to Build a Habitable Planet, Princeton University Press. (on Canvas and on reserve ebook)

Lovelock, J. 1987, Gaia : a new look at life on Earth, Oxford University Press.

Lunine, J., 1999, Earth: Evolution of a Habitable Planet, Cambridge Univ. Press. (on canvas and SciLi reserve)

Stanley, S.M., Earth Systems History, W.H. Freeman, NY. (on canvas and SciLi reserve)