**EART 206 -Great Papers in the Earth Sciences**

**Instructors**: Quentin Williams (qwilliam@ucsc.edu) and Terry Blackburn (terryb@ucsc.edu)

**Lecture**: M,W 2:30-4:05 E&MS Room D226
**Office Hours: 1:30-2:30M & 9:30-10:30W** (TB) E&MS A108 ,3-5 F (QW) E&MS A212 or by apptmt.
**Website:** Canvas

This course provides an opportunity for graduate students to explore the origins of a broad range of key issues in Earth Sciences by reading and leading discussions of classic papers that have been identified by the faculty. Most of the selected papers were key in the development of modern ideas in Earth Sciences. In many instances an early classic paper is paired with a more recent paper to emphasize subsequent evolution of the original ideas and to provide a modern perspective. In a few instances, a trend-setting idea was developed over a sequence of publications, and a review paper by the primary idea-developer is included. The instructor will lead discussions of a few of the classic papers and will provide contextual perspectives. The class also provides a chance for students to practice their critical thinking and hone their scientific presentation and discussion skills.

*Grading in the class will be based on attendance, participation, and presentations that students will give on the papers*. Students will choose the papers they will present at the first class meeting. Each presentation should lay out the logic and methods of the paper and cover the main conclusions. Historical context, on both the ideas and the lead authors, is relevant and welcome. **A one-page summary of main points, impact and background on the paper should be distributed to the class before each presentation**. In some cases, supplemental reading is supplied that will help presenters (and other class participants curious about the topic). Before making their presentations, students should feel free to touch base with the instructor or another faculty meeting to ensure that their thinking about the paper is on track. After the class at which the presentation is made, a copy of the presentation (electronic or paper) should be provided to QW.

All students are expected to read <u>every</u> assigned paper **and to submit a question, comment or talking point for each paper to the Canvas discussion board for that day's class**. Reading the papers in advance is essential and instructors may ask questions (a.k.a., give **pop quizzes** at their discretion) to ensure that everyone is preparing for the presentations by reading the papers.

## SYLLABUS

**Meeting 1. M 1/6 Introduction and Logistics**

**Age of the Earth**
**Meeting 2. W 1/8**

1. Kelvin, L., On the secular cooling of the Earth, *Trans. Royal Soc. Edinburgh, vol. XXIII*, 295-310, 1862. **(QW)**
1. Stacey, F.D., Kelvin's age of the Earth paradox revisited, *J. Geophys. Res., 105,* 13155-13158, 2000.

**Meeting 3. M 1/13**

1. Patterson, C., Age of meteorites and the earth, *Geochim. Cosmochim. Acta*, 10, 230-237, 1956.
2. Dalrymple, G.B., The age of the Earth in the twentieth century: a problem (mostly) solved, *in* Lewis, C.L. and Knell, S.J. (eds.), *The Age of the Earth: from 4004 BC to AD 2002*, Geological Society, London, Special Publications 190, 205-221, 2001. **(TB)**

**Meeting 4. W 1/15 Darwin and Evolution**

**1.** Darwin, C., Chapt. 15, *Origin of Species*, 353-374, 1859.
**2.** Eldredge, N., and S.J. Gould, Punctuated Equilibria: An Alternative to Phyletic Gradualism, pp. 82-115, in T.J.M. Schopf (ed.), Models in Paleobiology, Freeman, Cooper and Co., San Francisco, 1972. (Punctuated equilibrium: the paper that started it all, almost.).

Supplemental Reading
3. Mayr, E., Introduction, pp. vii-xxvii, in On the Origin of Species by Charles Darwin: A Facsimile of the First Edition, Harvard Univ. Press, Cambridge, MA, 1964. (The party line on Darwin and his role, written by one of the leading evolutionary biologists of the 20th [and early 21st] century. He died in 2005 at the age of 100, having written his last book at age 97.)

**Meeting 5. W 1/22 Origin of the Moon and Solar System Dynamics**

1. Canup, R., Forming a Moon with an Earth-like Composition via a Giant Impact, Science, 338, 1052-1055, 2012.
1. Cuk, M. and S.T. Stewart, Making the Moon from a Fast-Spinning Earth: A Giant Impact Followed by Resonant Despinning, Science, 338, 1047-1052, 2012.
2. M. Barboni et al., Early formation of the moon 4.51 billion years ago, Science Adv., e1602365, 2016.

**Meeting 6. M 1/27 Structure and Composition of the Earth**

1. Washington. The composition of the Earth. *American Journal of Science* v9, 1925.
2. Williamson, E.D. and Adams, L.H., Density distribution in the Earth*, J. Washington Academy of Sciences,* vol. 13, 413-428, 1923.

**Meeting 7. W 1/29 Crust-Mantle-Core differentiation**

1. Kemp, A.J.S. et al., Hadean crustal evolution revisited: New constraints from Pb-Hf systematics of the Jack Hills zircons, *Earth Planet. Sci. Letters*, 45-61, 2010.
1. Kleine, T. et al., Rapid accretion and early core formation on asteroids and the terrestrial planets from Hf–W chronometry, *Nature*, 418, 952-955, 2002

2. Allegre, C.J. and Turcotte, D.L., Implications of a two-component marblecake mantle, *Nature*, 323, 123-127, 1986.

**Meeting 8. M 2/3 Hotspots and Plumes**

1. Wilson, J.T., Evidence from islands on the spreading of ocean floors, *Nature,* 197, 536-538, 1963.
1. Morgan, W.J., Convection plumes in the lower mantle, *Nature* 230, 42-43, 1971.
2. Burke, K. and Dewey, J.F., Plume-generated triple junctions: Key indicators in applying plate tectonics to old rocks, *J. Geology* 81, 406-433, 1973**.**

**Meeting 9. W 2/5 Seafloor Spreading, Reversals, Subduction and Global Tectonics**

1. Wilson, J.T., A new class of faults and their bearing on continental drift, *Nature, 207*, 343-347, 1965**.**
1. Vine, F.J., Spreading of the ocean floor: New evidence, *Science, 154*, 1405-1415, 1966.
2. Atwater, T., Implications of plate tectonics for the Cenozoic tectonic evolution of western North America, *Geol. Soc. Am. Bull., 81,* 3513-3536, 1970**.**

**Meeting 10. M 2/10 Fluids in the Earth**

1. Darcy, H., The Public Fountains of Dijon, 1856. Translated by P. Brobeck, Appendix D- Determination of Laws of Water Flow Through Sand, App. 2D.
2. Neuzil, C.E., Osmotic generation of 'anomalous' fluid pressures in geological environments, *Nature, 403,* 182-184, 2000**.**

Supplemental Reading

1. Neuzil, C.E., Abnormal pressures as hydrodynamic phenomena, *Am. J. Sci.* 295, 742-786, 1995.

**Meeting 11. W 2/12**

1. Rubey, W.W., Geologic history of sea water, *Geol. Soc. Am. Bull. 62*, 1111-1148, 1951.
2. Hirth, G. and Kohlstedt, D.L., Water in the oceanic upper mantle: implications for rheology, melt extraction and the evolution of the lithosphere, *Earth Planet. Sci. Letters 144*, 93-108, 1996.

**Meeting 12. W 2/19 Atmospheres, Climate and Surface Processes**

1. Arrhenius, S. S., On the influence of carbonic acid in the air upon the temperature on the ground, *Phil. Mag*., 41, 237-276, 1896. **(QW)**

**Meeting 13. M 2/24 Atmosphere and Ocean Evolution**

1. Sagan, C. and Mullen, G., Earth and Mars: Evolution of atmospheres and surface temperatures, Science, 177, 52-56, 1972.
2. Bekker, A., Holland, H.D., Wang, P.L., Rumble III, D., Stein, H.J., Hannah, J.L., Coetzee, L.L. and N.J. Beukes, Dating the rise of atmospheric oxygen, Nature, 427, 117-120, 2004.

**Meeting 14. W 2/26**

1. Croll, J. On the excentricity of the Earth's orbit, and its physical relations to the glacial epoch , The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science, 33:221, 119-131, 1867.
2. Urey, Harold Clayton, et al. "Measurement of paleotemperatures and temperatures of the Upper Cretaceous of England, Denmark, and the southeastern United States." *Geological Society of America Bulletin* 62 (1951): 399-416.

**Meeting 15. M 3/2**

1. Hays, J.D., Imbrie, J., and Shackleton, N.J., Variations in the earth's orbit. Pacemaker of the ice ages. Science, 194, 1121-1132, 1976.
2. Petit et al., Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica, Nature, 399, 429-435, 1999.

**Meeting 16. W 3/4 Building and killing mountains**

1. Gilbert GK The convexity of hill tops, *J*. Geol., 17, 344–350, 1909.
1. Clark, M.K, and Royden, L.H., Topographic ooze: Building the eastern margin of Tibet by lower crustal flow, *Geology, 28,* 703-706, 2000.
2. Molnar, P., and P. England, Late Cenozoic uplift of mountain ranges and global climate change: chicken or egg?, *Nature,* 346, 29-34, 1990.
2. France-Lanord, C., and Derry, L.A., Organic carbon burial forcing of the carbon cycle from Himalayan erosion, *Nature 390,* 65-67, 1997.

**Hard Times on the Planet**

**Meeting 17. M 3/9**

1. Alvarez, L.W. et al., Extraterrestrial cause of the Cretaceous/Tertiary extinction: experimental results and theoretical implications. *Science, 208*, 1095-1108, 1980.
2. Knoll, A.H., Bambach, R.K., Payne, J.L., Pruss, S. and Fischer, W.W., Paleophysiology and end-Permian mass extinction, *Earth Planet. Sci. Letters*, *256,* 295-313, 2007.
2. S.D. Burgess, J.D. Muirhead and S.A. Bowring, Initial pulse of Siberian Traps sills as the trigger of the end-Permian mass extinction. Nature Comm., 8: 164, 2017.

**Meeting 18. W 3/11**

1. Harland, W.B. and Rudwick, M.J.S., The great infra-Cambrian ice age, *Sci. Am.*, 211, 28-36, 1964. **(Andy)**
1. Kirschvink, J.L., Late Proterozoic low-latitude global glaciation: The snowball Earth, in *The Proterozoic Biosphere*, J.W. Schopf and C. Klein, Eds., p. 51-52, Cambridge U. Press, 1992.
2. Hoffman, P.F., Kaufman, A.J., Halverson, G.P., Schrag, D.P., A Neoproterozoic snowball Earth, *Science*, 281, 1342-1346, 1998.

Supplemental Reading

Hoffman, P.F. and Schrag, D.P., The snowball Earth hypothesis: testing the limits of global change, Terra Nova, 14, 129-155, 2002.

**Meeting 19. Modern Atmospheres**
**Date: Either 3/16 at our normal time or during the "final exam" meeting time T 3/17 12pm-3;**

1. Keeling, C.D., R.B. Bacastow, A.E. Bainbridge, et al., Atmospheric carbon-dioxide variations at Mauna Loa Observatory, Hawaii, *Tellus, 28*, 538-551, 1976.
2. Molina, M.J. and F.S. Rowland, Stratospheric sink for chlorofluoromethanes - chlorine atomic-catalysed destruction of ozone, *Nature, 249*, 810-812, 1974.