SIOG 242 Sect. ID 975237-Rates and Dates: Geochronologic Methods and Applications

SYLLABUS WINTER 2020

Class meeting time: Monday and Wednesday 12:30-1:50pm Room: VH210
Prof: Jane Willenbring jwillenbring@ucsd.edu
Office Hours: Fri: 1pm-2pm, Mon-Wed after class – or – e-mail me to set up a time
**Suggested pre-requisites: Introductory Chemistry or Physics and Introductory Geology*

Advances in dating methods have revolutionized scientists' understanding of how the Earth and its inhabitants have changed over time. This course is designed to give graduate students (and advanced undergraduate students) an understanding of the science behind numerical dating techniques in geological, archaeological and environmental science contexts. This course will provide a background in the physics of radioactive decay and natural radiation sources. We will also cover various radiometric dating methods, and non-radiometric alternatives. We will focus on tools and concepts and hands-on measurements made rather than 'facts'. In this context, we will analyze numerous case studies involving questions of both geological and archaeological importance. This class will cater to students interested in geology, archeology, paleontology, physical anthropology, environmental science, soil science, tectonics, sea level change, climate change, land use change and ocean processes. All students will write a Geological Society of America-style proposal or a National Geographic Society-style proposal focusing on a technique used in their own research that may be submitted to GSA or NGS for funding. Group student projects will be prepared for submission to a peer-reviewed journal for publication.

Grading: I hope that you always focus on learning and thinking about the material that we cover. If you do this, good grades will follow. However, the obligatory grading scheme is below.

Take-home Test/Group Project	200 points
Final Proposal and Presentation	200 points
Class Discussion + Participation + Homework (8 sets/25 pts. each)	200 points
TOTAL	**600 points**

Rules:
Laptops and similar items can be used for note taking but please don't check email during class. Homework and take home exams must be turned in at/before class time on the due date. **Late submissions will not be graded unless cleared in advance.** Just send me an email; I'm a reasonable person. E-mail submissions (of pdf or doc files) of homework are fine. **If you actively participate in class discussions, you can drop your lowest homework and double count your second lowest mark.**

Opportunities:
My hope is that this class could result in submission of one peer-reviewed publications and a proposal you can submit for funding. *Please, take advantage of the small size of this class and feel free to talk to me about problems or suggestions you have. Tell me if you are extra-interested (or confused) about any material covered in class!*

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Week 1: Jan. 8, *Jan. 10*

Intro … Elements, Isotopes, Cosmic radiation and Radioactive decay Dendrochronology, Varves, and Ice cores Review of the periodic table, Table of the Nuclides, isotopes, radioactive decay. Countable layers offered one of the earliest chronometers.

***Special class time: Jan 10 at 3:00pm-4:10pm in Social Sciences Building Room 107**
Dr. Tammy Rittenour, Assoc. Prof./Director of the Luminescence Lab at Utah State Univ.
"A Million Years of Coastal Dunes and Linkages to Sea Level Change on the Sunshine Coast, Australia"

Readings: (1) Chapter 1 in Dickin, 2005. *Radiogenic Isotope Geology.* p. 1-2, 7-13. (2) Walker. 2005. Quaternary Dating Methods, chapter 1: p. 1-9. Readings: (3) Walker, M., 2005. Quaternary Dating Methods. pp. 121-130.

HANDOUT HOMEWORK 1

Week 2: Jan. 14, Jan. 16

Radiocarbon Dating

Production of ^{14}C in the atmosphere. Incorporation into living material, preservation. Changes in atmospheric ^{14}C concentrations over time. The radiocarbon calibration curve. AMS dating to understand forest fire timing, flooding and age of terrestrial Carbon. Pitfalls and promise. Archaeological uses.

Readings: (1) Dickin, A. P., 2005. Radiogenic Isotope Geology. pp. 361-398.
(2) Walker, M., 2005. Quaternary Dating Methods. pp. 17-55. (3) Hilton, R. G. et al. 2008. Tropical-cyclone-driven erosion of the terrestrial biosphere from mountains. Nature Geosci. 1: 759–762. (4) Chiverrell, R.C. et al. 2011. Cumulative Probability functions and their role in evaluating the chronology of Geomorphological events during the Holocene. Journal of Quat. Science 26: 76-85.

HANDOUT HOMEWORK 2 / HOMEWORK 1 DUE

Week 3: Jan. 21, Jan. 23

Cosmogenic nuclides

Direct dating of exposed glacial deposits and buried river sediment. The cosmogenic isochron technique applied to the Peking Man. The 'age' of eroding soil profiles.

Readings: (1) Elements issue on cosmogenic nuclides. (2) Walker, M., 2005. Quaternary Dating Methods. pp. 121-130. (3) Dickin, A. P., 2005. Radiogenic Isotope Geology. pp. 414-422. (4) Guanjun, S. et al. 2009. Age of Zhoukoudian Homo erectus determined with $^{26}Al/^{10}Be$ burial dating. Nature 458: 198-200. (5) Heimsath, A.M., Dietrich, W.E., Nishiizumi, K. and Finkel, R.C., 1997. The soil production function and landscape equilibrium. Nature 388: 358-361.

HANDOUT HOMEWORK 3 / HOMEWORK 2 DUE

Week 4: Jan. 28, Jan. 30

Meteoric Beryllium-10 and Introduce Student Hands-on Group Project I

Dating techniques and sediment tracing related to a long-lived fallout radionuclide. Challenges and opportunities. The cosmogenic decay technique applied to the African early hominid fossil. The 'age' of eroding and moving soil.

Readings: (1) Dickin, A. P., 2005. Radiogenic Isotope Geology. pp. 402-422. (2) Willenbring, J. and von Blanckenburg, F. 2010. Meteoric cosmogenic Beryllium-10 adsorbed to river sediment and soil: Applications for Earth-surface dynamics. Earth-Science Reviews 98: 105–122. (3) Lebatard, A.-L., et al. 2008. Cosmogenic nuclide dating of *Sahelanthropus tchadensis* and *Australopithecus bahrelghazali*: Mio-Pliocene hominids from Chad. PNAS *105: 3226-3231. (4)* Mackey, B., Roering, J., McKean, J. 2009. Long-term kinematics and sediment flux of an active earthflow, Eel River, California, Geology 37: 803-806.

HANDOUT HOMEWORK 4 (4/22) / HOMEWORK 3 DUE (4/24)

Week 5: Feb. 4, Feb. 6

Fallout Radionuclides and Introduce Student Hands on Group Project II

Dating techniques and sediment tracing related to fallout radionuclides. Challenges and opportunities.

Readings: (1) Walker, M., 2005. Quaternary Dating Methods. pp. 85-92**.** (2) Kaste, J.M., Elmore, A.J., Vest, K.R. and Okin, G.S., 2016. Groundwater controls on episodic soil erosion and dust emissions in a desert ecosystem. *Geology*, *44*(9), pp.771-774.
(3) Aalto, R. 2003. Episodic sediment accumulation on Amazonian floodplains influenced by ENSO. Nature *425*: 493-497.

HANDOUT HOMEWORK 5 (4/29) / HOMEWORK 4 DUE (5/1)

May 4th *Optional* - SoCal Geomorphology mini-Symposium ALL DAY

Week 6: Feb. 11, Feb. 13

Radiation exposure dating (TL, OSL, and ESR)

Direct dating of buried geological material and archaeological remains. Case studies: Dating dunes, human migration into South America.

Readings: (1) Walker, M., 2005. Quaternary Dating Methods. pp. 93-113.
(2) Aitken, M. J., 1994. Optical dating: A non-specialist review. Quaternary Science Reviews, v. 13, pp. 503-508. (3) Heimsath, A.M., Chappell, J.C., Spooner, N.A., Questiaux, D.G., 2002. Creeping soil. Geology 30(2): 111-114. (4) Arnold, L.J., et al. 2011. Paper II–dirt, dates and DNA: OSL and radiocarbon chronologies of perennially frozen sediments in Siberia, and their implications for sedimentary ancient DNA studies. *Boreas*, *40*(3), pp.417-445.

HANDOUT HOMEWORK 6 (5/6) / HOMEWORK 5 DUE (5/8)

Week 7: Feb. 18, Feb. 20

U-decay series dating: Use of short-lived decay products to date young materials. Applications to Quaternary climate studies, aquifer residence time and soil production.

Readings: (1) Dickin, 2005. Radiogenic Isotope Geology. Chapter 12: pp. 324-349. (2) Walker, M., 2005 Quaternary Dating Methods. pp. 66-77. (3) Stock, G.M., Granger, D.E., Sasowsky, I.D., Anderson, R.S. and Finkel, R.C., 2005. Comparison of U–Th, paleomagnetism, and cosmogenic burial methods for dating caves: implications for landscape evolution studies. *Earth and Planetary Science Letters*, *236*(1-2), pp.388-403.
(4) Dosseto, A., Turner S.P., Chappell, J. 2008. The evolution of weathering profiles through time: new insights from uranium-series isotopes. Earth Planet. Sci. Lett. 274: 359-371.

HANDOUT HOMEWORK 7 (5/13) /HOMEWORK 6 DUE (5/15)

Week 8: Feb. 25, Feb. 27

U-Th/He and Fission Track Dating

Radioactive decay in the U-Pb system. U-Th/He dating of more recent deposits. Case studies: Dating and tracing sediments, Uplift and exhumation.

Readings: (1) Dickin, A. P., 2005. Radiogenic Isotope Geology. pp. 101-117, 451-469. (2) Walker, M., 2005. Quaternary Dating Methods. pp. 114-120. (3) Stock, G.M., Ehlers, T.A. and Farley, K.A., 2006. Where does sediment come from? Quantifying catchment erosion with detrital apatite (U-Th)/He thermochronometry. Geology 34: 725-728. (4) Schildgen, T.F., van der Beek, P.A., Sinclair, H.D. and Thiede, R.C., 2018. Spatial correlation bias in late-Cenozoic erosion histories derived from thermochronology. Nature, 559(7712), p.89.

HANDOUT HOMEWORK 8 / HOMEWORK 7 DUE

Optional Field Trip – Feb. 29

Week 9: Mar. 3, Mar. 5

K/Ar and $^{40}Ar/^{39}Ar$ geochronology

Radioactive decay in the K-Ar-Ca system. Methods, advantages, shortcomings.
Case study: Olduvai Gorge, Tanzania. Advances in K-Ar dating. Modern techniques and applications. Case study: Dating Lucy and Dry Valleys ash deposits.
Readings: (1) Ch. 10 in Dickin, 2005. K-Ar and Ar-Ar dating. Pages 254-276.
(2) Walker, M., 2005. Quaternary Dating Methods. pp. 57-66. (3) Hay, 1992. Potassium-Argon dating of Bed I, Olduvai Gorge, 1961-1972. Quaternary International 13-14: 31-36. (4) Walter, R.C. et al., 1992. Laser-fusion $^{40}Ar/^{39}Ar$ dating of Bed I, Olduvai Gorge, Tanzania. Nature 354 :145-149.

HOMEWORK 8 DUE

Week 10: Mar. 10, Mar. 12

Mar. 10 Student proposal presentations. Mar 12: Group Project Work – No formal class
Final Proposal Due via email jwillenbring@ucsd.edu
Group Project -or- Takehome exam Due via email jwillenbring@ucsd.edu