

	Course	GEOS 5375 - TECTONICS
	Professor	Dr. Robert J. Stern
	Term	Spring 2025
	Meetings	Online synchronous MW11:30-12:45

Professor's Contact Information

Office Location & hours	On-line, email me for an appointment
Email Address	rjstern@utdallas.edu
TA	Clint Crowley clinton.crowley@utdallas.edu

General Course Information

Pre-requisites, Co-requisites, & other restrictions	None, but Structural Geology is strongly recommended
Course Description	Study of the Earth's present tectonic environments, including geochemistry, sedimentology, and structure; application of present tectonic environments towards reconstructing ancient crustal events; consideration of temporal aspects of crustal evolution. Oral presentation required. Recommended: Structural geology. (3-0) T
Learning Outcomes	Students will learn the various modes of formation and deformation of Earth's crust and lithosphere
Required Texts & Materials	Kearey, Klepeis, & Vine (2009) <u>Global Tectonics</u> (Third Edition, Wiley-Blackwell)
Supplementary Materials	http://blackwellpublishing.com/kearey/

Important Message: Tectonics is a wonderfully interdisciplinary field that draws from many geoscientific disciplines. Tectonic processes and products are of interest to academia, governmental agencies interested in resources and natural hazards, and the mineral and hydrocarbon industries. It is my favorite class to teach. I assume that all students in this class know the geologic timescale. I will frequently refer to eras (Paleozoic, Mesozoic, Cenozoic) and periods (Cambrian, Triassic, etc.) and also ages of events in millions of years (Ma) and billions of years (Ga) ago. These ages are likely to show up on exams. If you are not comfortable with this terminology, print out and study the latest timescale <https://www.geosociety.org/documents/gsa/timescale/timescl.pdf>

Grading

20% on each of 4 midterms.

Final is also worth 20%. Lowest midterm grade is dropped if you take the final.

Final Exam is optional if you've done well on all 4 midterms.

All questions are from the book, not the lecture notes!

5% for 1 paragraph proposal for oral presentation (due March 5)

15 % for oral presentation

- **INFO ABOUT ORAL PRESENTATIONS:** Oral presentation will be one talk (9 slides max) given on some problem in Tectonics. You will identify a problem in tectonics that you find interesting; students are encouraged to discuss possibilities with professor and/or TA. You will submit as a short (few sentences) written proposal on March 5. You will give your talk to the class as a powerpoint on May 7. **Each presentation must consist of a total of exactly 9 powerpoint slides, including 1 title slide and 1 reference slide (references must be in the format of Journal of Geophysical Research) as well as 1 location slide created in GeoMapApp** <http://www.geomapapp.org>. *GeoMapApp* is an Earth science exploration and visualization application that is part of the Marine Geoscience Data System at the Lamont-Doherty Earth Observatory of Columbia University (The application accesses the Global Multi-Resolution Topography compilation that hosts high resolution bathymetry and topography.) **The other 6 slides must be made by the student.** Figures do not need to be computer-generated, they can be sketched or traced but they **must** be generated by each student; points will be subtracted if any figures are not made by student. The total presentation can take no more than 10 minutes plus 5 minutes for questions.
- **INFO ABOUT EXAMS & LECTURES:** Exams are multiple choice, all questions are from Kearey et al. text. No missed tests can be made up, you can drop one poor test score (including a zero) and take the final to make up for it. My lectures *supplement* the book. I will post my Powerpoints on e-learning. TA will have your graded exams and you can look at these by asking him.

Class Schedule (* indicates supplementary information and reading; most articles can be downloaded from elearning)

Jan. 22: Introduction to Syllabus and Course

Jan. 27: Planetary Tectonics (Lecture 1; Part 1) 130 slides

Kearey et al. Chapter 1 (8p)

- * Stern, R.J., Gerya, T., and Tackley, P., 2018. Planetoid Tectonics: Perspectives from Silicate Planets, Dwarf Planets, Large Moons, and Large Asteroids. *Geoscience Frontiers* 9, 103-119.
- * Stern, R.J., Gerya, T. V., and Tackley, P., 2023. A Tectonic Manifesto. *Perspectives of Earth and Space Scientists* 4 e2023CN000214. <https://doi.org/10.1029/2023CN000214>

Jan. 29: Planetary Tectonics (Lecture 1; Part 2)

Feb. 3: The Interior of the Earth: Crust & Lithosphere Lecture 2.

Kearey et al. Chapter 2 (42p)

- *Morris, 2003. A paleomagnetic and rock magnetic glossary. *Tectonophysics* 377, 211-228
- *Fault plane solutions: <https://www.youtube.com/watch?v=MomVOkyDdLo>

*Earthquake epicenters: <https://flexbooks.ck12.org/cbook/ck-12-middle-school-earth-science-flexbook-2.0/section/6.15/primary/lesson/locating-earthquake-epicenters-ms-es>

*GD Paleomagnetism: https://www.youtube.com/watch?v=jDHmXH_qzXY

NOAA website of every recorded earthquake from Jan 1, 2001 to Dec 31, 2015:

<https://www.youtube.com/watch?v=ph7Eczs-nTI>

Feb. 5: Continental Drift Lecture 3 47 slides

Kearey et al. Chapter 3 (14 p)

*Newman, 1995. American Intransigence: The Rejection of Continental Drift in the Great Debates of the 1920'S. Earth Sciences History 14, 62-83

*Scotese 2004. A Continental Drift Flipbook. J. Geology 112, 729-741

Continental drift short videos:

Continental Drift Pangea Final (1.5 minutes):

<https://www.youtube.com/watch?v=UvIDxu7twpc>

Scotese Plate Tectonics Paleogeography & Ice ages (1.6 minutes):

<https://www.youtube.com/watch?v=UevnAq1MTVA>

A new model of plate tectonic evolution from 1 Billion years ago to the present (7.5 mins.) <https://www.youtube.com/watch?v=IY6D1eR3mM4>

Euler poles (video): https://www.youtube.com/watch?v=_0mdH8NtJXE

Feb. 10: Seafloor Spreading and Transform Faults Lecture 4 63 slides

Kearey et al. Chapter 4 (17 pages)

Look at videos

Go to Plate Tectonic Basics 1, look at first 2 minutes:

<https://www.youtube.com/watch?v=6wJBOK9xjto>

Look at Digital Isochrons of the World's Ocean Floor

https://www.earthbyte.org/Resources/Agegrid/1997/digit_isochrons.html#:~:text=The%20cob_polygons%20are%20%28lat%2Flon%20format%29%3A%20%20%20afr_cob.yx,%20%20Caribbean%20%2010%20more%20rows%20

Some animations that will give a good idea how the San Andreas fault of California formed:

Pacific Hemisphere Plate, 80 Ma to Present

http://emvc.geol.ucsb.edu/2_infopgs/IP3RegTect/dNoPacific.html

N.E. Pacific and W. North America Plate History, 38 Ma to Present

http://emvc.geol.ucsb.edu/2_infopgs/IP4WNACal/bNEPacWNoAmer.html

Plate Tectonic History of Southern California, 20 Ma to Present

http://emvc.geol.ucsb.edu/2_infopgs/IP4WNACal/dSoCalifTect.html

Tanya Atwater's illustrated talk about the early days of plate tectonics. <https://www.youtube.com/watch?v=zr8L1-5vaq4>

GPlates is open-source application software offering a novel combination of interactive plate-tectonic reconstructions, geographic information system (GIS) functionality and raster data visualization. Here are some places where you can start learning more about GPlates:

<https://en.wikipedia.org/wiki/GPlates>
https://www.youtube.com/watch?v=mO_Z6z9ACQc

If anyone wants to learn how to use GPlates, tutoring can be arranged.

Feb. 12: **Midterm #1** (Kearey et al. Chs. 1-4)

Feb. 17: **The Interior of the Earth: Geophysical Techniques Lecture 5; Part 1** 80 slides GUEST LECTURER: Dr. Walter Mooney, USGS

- *Anderson, D.L. (1995) "Lithosphere, asthenosphere, and perisphere" Reviews of Geophysics v. 33, p. 125-149.
- *Mooney, W.D., Barrera-Lopez, C, Suarez, M.G., Castelblanco, M.A., 2023. Earth Crustal Model 1 (ECM1): A 1° x 1° global seismic and density model, Earth-Science Reviews, 243, doi:10.1016/j.earscirev.2023.104493
- * Wang, Y., Liu, L., & Zhou, Q. (2022). Topography and gravity reveal denser cratonic lithospheric mantle than previously thought. Geophysical Research Letters, 49, e2021GL096844. <https://doi.org/10.1029/2021GL096844>

Feb. 19: **The Interior of the Earth: Geophysical Techniques Lecture 5; Part 2**

GUEST LECTURER: Dr. Walter Mooney, USGS)

Feb. 24: **The Interior of the Earth: Rheology Lecture 6** 49 slides

- *Maggi, Jackson, McKenzie, and Priestley, 2000. Earthquake focal depths, effective elastic thickness, and the strength of the continental lithosphere. Geology 28, 495-498
- *Jackson, 2002. Strength of the continental lithosphere: Time to abandon the jelly sandwich? GSA Today, 4-9
- *Brittle Deformation of rocks (Video):
<https://www.youtube.com/watch?v=UjuoObf9zIU&t=28s>
- *Ductile Deformation of rocks (Video, French):
https://www.youtube.com/watch?v=GCv_curT6j0

Feb. 26: **The Framework of Plate Tectonics Lecture 7 Part 1** (97 slides)

Kearey et al., Chapter 5 (29 pages)

- *DeMets et al., 1990, "Current Plate Motions" Geophys. J. Int'l. 101, 425-478
- *DeMets et al. 1994. "Effect of Recent revisions to the Geologic Time Scale on estimates of current plate motions" Geophys. Res. Lett. 21, 2191-2194.
- *Sella et al., 2002. "REVEL: A model for current plate velocities from space geodesy" J.Geophys. Res. 107, B4, 10.1029/2000JB000033, 2002
- *Bird, 2003. "An updated digital model of plate boundaries" Geochemistry, Geophysics, Geosystems v. 4, no. 3, 1027, doi:10.1029/2001GC000252

- *DeMets, C., Gordon, R. G., and Argus, D. F., 2010. Geologically current plate motions, *Geophysical Journal International*, v. 181, no. 1, p. 1-80, doi: 10.1111/j.1365-246X.2009.04491.x
- *Argus, D. F., Gordon, R. G., and DeMets, C., 2011. Geologically current motion of 56 plates relative to the no-net-rotation reference frame, *Geochemistry, Geophysics, Geosystems*, DOI: 10.1029/2011GC003751.
- * Video: Plate Tectonics: <https://www.youtube.com/watch?v=6beUTsVq-6I>
- *Video: Velocity Field Models. <https://www.youtube.com/watch?v=NqxAA6a0xG0>

March 3: **The Framework of Plate Tectonics Lecture 7 Part 2**

March 5: **Ocean Ridges Lecture 8** 69 slides PROPOSAL DUE
Kearey Chapter 6 (27 p.)

- *Seton, M., Müller, R. D., Zahirovic, S., Williams, S., Wright, N. M., Cannon, J., et al. (2020). A global data set of present-day oceanic crustal age and seafloor spreading parameters. *Geochemistry, Geophysics, Geosystems*, 21, e2020GC009214. <https://doi.org/10.1029/2020GC009214>

March 10 **Continental Rifts and Rifted Margins Lecture 9 Part 1** 129 slides
Kearey Ch. 7 (56 p.)

- * Brune, S., Kolawole, F., Olive, J.A., Stamps, D.S., Buck, W.R., Buiter, S.J., Furman, T. and Shillington, D.J., 2023. Geodynamics of continental rift initiation and evolution. *Nature Reviews Earth & Environment*, 4(4), pp.235-253.
- *Sengor, A.M.C., and Natal'in, B.A., 2001, Rifts of the World, in Ernst, R.E., and Buchan, K. I. eds., *Mantle Plumes: Their Identification Through Time*. GSA Spec. Paper 352, p. 389-482
- *Sengor and Burke, 1978. Relative Timing of Rifting and Volcanism on Earth and its Tectonic Implications *Geophys Res Lett.* 5, p. 419-421
- *Buck, W.R., (1991) Modes of Continental Lithospheric Extension, *J. Geophysical Research* vol. 96 no. B12. P. 20,161-20,178.
- *Taylor, Goodliffe, and Martinez (1999) How continents break up: Insights from Papua New Guinea. *JGR* v. 104, p. 7497-7512

VIDEOS

Plate Tectonic Basics 2: Continental Rifts. New Ocean Basins, and Passive Continental Margins (7 minutes) <https://www.youtube.com/watch?v=HQqrfIVkctM>
Africa-Tectonic Setting and Historic Earthquakes
<https://www.youtube.com/watch?v=dJndGhTa1Xo>

March 12: **Continental Rifts and Rifted Margins Part 2**

- *Wikipedia entries: “Passive Margin”, “Volcanic Passive margin” and “Non-volcanic passive margin”. These were created by UTD students
- *Skogseid 2001. “Volcanic Margins: Geodynamic and Exploration Aspects” *Marine and Petroleum Geology*, 18: 457-461.

*Berndt, Planke, Alvestad, Tsikalas, and Rasmussen. 2001. Seismic volcanostratigraphy of the Norwegian margin: Constraints on tectonomagmatic break-up processes. J. Geol. Soc. London 158, 413-426

March 17, 19: No class, Spring Break

March 24: **Midterm #2 (Kearey Chs. 5-7)**

March 26: **Continental Transforms and Strike-Slip Margins Lecture 10** 87 slides
Kearey et al. Ch. 8 (36 pages)

Look at

IRIS Transform Faults – San Andreas (32 secs.)

<https://www.youtube.com/watch?v=tIuk2bIBzHs>

Transform Plate Boundaries (6 minutes)

<https://www.youtube.com/watch?v=tuKNtQ7Hupg>

Earthquake - A narrated fly-by down the North Anatolian fault at the site of the 1999 Izmit shock (1 minute) <https://www.youtube.com/watch?v=px-EPnLgzKg>

March 31: **Subduction Zones Lecture 11 Part 1** (132 slides)

Kearey et al. Ch. 9 (32p.)

*Stern (2003) “Subduction Zones” Reviews of Geophysics, 40, 4 (38 pages)

*Clift and Vannucchi, 2004. Controls on Tectonic Accretion versus Erosion in Subduction Zones: Implications for the Origin and Recycling of the Continental Crust. Reviews of Geophysics, 42, RG2001, doi:10.1029/2003RG000127.

*von Huene, Ranero, and Vannucchi, 2004. Generic model of Subduction erosion. Geology 32, 913-916.

Go to Plate Tectonic Basics 1, look at part after 2:00 to the end.

<https://www.youtube.com/watch?v=6wJBOK9xjto>

Slab 2.0 global compilation of subduction zones:

Hayes, G., 2018, Slab2 - A Comprehensive Subduction Zone Geometry Model: U.S. Geological Survey data release, <https://doi.org/10.5066/F7PV6JNV>.

April 2: **Subduction Zones Lecture 11 Part 2**

April 7: **Orogenic Belts Lecture 12 Part 1** (102 slides)

Kearey et al. Ch. 10 (56 p)

*Cloos, M. (1993) “Lithospheric buoyancy and collisional orogenesis: Subduction of oceanic plateaus, continental margins, island arcs, spreading ridges, and seamounts” Geological Society of America Bulletin, v. 105, p. 715-737.

*Mann, P., and Taira, A., 2004. Global tectonic significance of the Solomon Islands and Ontong Java convergent zone. Tectonophysics 389, 137-190

*Avouac, J.-P., 2015, 6.09. Mountain Building: From Earthquakes to Geologic Deformation. (G. Schubert, ed.) Treatise on Geophysics (2nd Ed.), vol 6., 381-432.

Look at http://emvc.geol.ucsb.edu/2_infopgs/IP1GTect/dContCollision.html “India-Asia Continental Collision movie”

April 9: **Orogenic Belts Lecture 12 Part 2**

April 14: **Midterm #3 (Kearey Chs. 8-10)**

April 16: **Precambrian tectonics and the Supercontinent Cycle Lecture 13** (63 slides)
Kearey et al. Ch. 11 (28p)

*Rollinson 2008. When did plate tectonics begin? *Geology Today* 23, 186-191.

* Stern, R.J., 2018. The Evolution of Plate Tectonics. *Philosophical Transactions A*, 376, 20170406 DOI 10.1098/rsta.2017.0406

*Murphy, J.B., and Nance, R.D., 2013. Speculations on the mechanisms for the formation and breakup of supercontinents. *Geoscience Frontiers* 4, 185-194.

April 21: **The Mechanism of Plate Tectonics Lecture 14** (55 slides)

Kearey et al. Ch. 12 (22p.)

*Conrad and Lithgow-Bertelloni (2002) How mantle slabs drive plate tectonics
Science, vol. 298, no.5591, pp.207-209, 04 Oct 2002 *

*Bird P., Z. Liu, W. K. Rucker (2008), Stresses that drive the plates from below: Definitions, computational path, model optimization, and error analysis, *J. Geophys. Res.*, 113, B11406, doi:10.1029/2007JB005460.

Watch 7.5 min video: What drives the plates?

<https://www.youtube.com/watch?v=hUtYyRUBdZQ>

April 23: **Implications of Plate Tectonics Lecture 15** (77 slides)

Keary et al. Ch. 13

April 28: **The Evolution of Plate Tectonics**

*Stern, R.J., 2018. The Evolution of Plate Tectonics. *Philosophical Transactions A*, 376, 20170406 DOI 10.1098/rsta.2017.0406

* Stern, R.J., 2020. The Mesoproterozoic Single Lid Tectonic Episode: Prelude to Plate Tectonics. *GSA Today* 30(12), 4-10

* Stern, R. J., 2023. The Orosirian (1800-2050 Ma) Plate Tectonic Episode: Key for Reconstructing the Proterozoic Tectonic Record. *Geoscience Frontiers* 14, 101553.

April 30: **Midterm #4** (Kearey Ch. 11-13)

May 5: **TBD**

May 7: **Oral presentations**

May X: **Final exam**

Some Useful links:

- <http://topex.ucsd.edu/index.html> Satellite geodesy website. Global topography (including bathymetry); satellite radar altimetry (including free-air gravity).
 - <http://www.geomapapp.org> *GeoMapApp* is an Earth science exploration and visualization application that is part of the Marine Geoscience Data System) at the Lamont-Doherty Earth Observatory of Columbia University. The application accesses the Global Multi-Resolution Topography compilation that hosts high resolution bathymetry and topography.
 - <http://earthquake.usgs.gov> US national earthquake information service. Earthquake Hazards Program, maps of seismicity, etc.
 - <http://www.iris.edu/hq/> Incorporated Research Institutes for Seismology (IRIS) website. Includes Global Seismograph Network data.
 - <http://volcano.si.edu> Smithsonian Global Volcanism Program
 - www.mantleplumes.org/ Website for discussion of the origin of hotspot volcanism.
 - www.world-stress-map.org World Stress Map project website. Global database of present-day stress in the lithosphere from various types of stress indicator. Includes world and regional maps of stress measurements.
 - www.marine-geo.org Marine Geoscience Data System. Includes Ridge 2000 and MARGINS programs, relating to mid-ocean ridge crests and continental margins respectively.
- www.ngdc.noaa.gov National Geophysical Data Center of the U.S. National Oceanographic and Atmospheric Administration. Includes Marine Geology and Geophysics, Bathymetry and Global relief and Natural Hazards.