GEOL 3443: Structural Geology Course Syllabus Fall 2015

Basic Course Information:

Course number: GEOL 3443-001

Time:

- Lecture MWF 9:00 – 9:50 AM
- Lab 1: M 10:00 – 12:50 PM
- Lab 2: W 10:00 – 12:50 PM

Location:

- Lecture: GS 104
- Lab: GS 233

Primary Text:

Students are required to purchase lecture and laboratory textbooks. A supplementary text which is still in draft form will also be used extensively, but this will be provided free of charge to students.

- Lecture: H. Fossen, *Structural Geology*, Cambridge University Press, 2010
- Lab: S. Marshak and G. Mitra, *Basic Methods of Structural Geology*, Prentice Hall, 1988.
- Supplementary Text: *D. Pollard* and *S. Martel*, Structural Geology: A Quantitative Introduction (Available on)

Instructor Information:

- **Instructor:** Dr. W. Ashley Griffith
  - **Faculty Profile:** https://mentis.uta.edu/public/#profile/profile/edit/id/11631/
  - **Office:** GS 233A
  - **Office hours:** Mon 1:30AM-3:30PM, Wed 1:30PM-3:30PM or by email appointment*
  - **Phone: 817-272-9666**
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- **TA:** Rene St Julien
  - **Office:** GS 244
  - **Office hours:** T 12:00pm - 1:30pm, TH 12:00pm - 1:30pm or by email appointment*
  - **email:** rene.stjulien@mavs.uta.edu

*We work hard to be helpful and approachable outside of class; however please be considerate and send us an email to schedule time for help if you need it outside of the scheduled office hours.

Course Description:

Structural geology is the study of deformation in the earth's crust. This deformation is heterogeneous: it happens at various scales, locations, and times; this deformation produces identifiable structures in the crust such as fractures and folds. An appreciation of earth structures has both enormous practical value and profound intellectual implications for how we view this planet. We start out with an introduction to classical *descriptive* structural geology

which is concerned with constructing *geometric models* of structures and then we proceed with an introduction to physics-based methods to analyze the *mechanical processes* involved in the formation of geologic structures. Due to the difficulty of the material, we will follow a less-is-more strategy. Students will learn to critically observe, map, and describe rock structures, including folds, fractures, and shear zones at the scales ranging from microscopic to tectonic scales. Special emphasis will be given to critical thinking and quantitative analysis. Laboratory exercises will include practice of geologic mapping skills, an introduction to structural analysis at various scales, and basic mechanical modeling using computers.

Course goals/Student learning outcomes:

At the conclusion of this class, students should be able to:

- quantitatively describe the three dimensional structure of rocks in the earth's crust using geologic maps and/or outcrop data
- Reconstruct the deformation history (chronology of events) of deformed rocks based on fabrics and geometric relationships
- Differentiate between recoverable (elastic) and non-recoverable (brittle, plastic, or viscous) deformation
- Quantitatively describe strain and stress transformations
- Relate strains to stresses through constitutive equations
- Use Matlab© to conduct and visualize rigid body translations and rotations, perform strain and stress transformations, and to perform basic mechanical analyses using theories of elasticity and brittle failure
- Critically read and communicate technical literature in the field of Structural Geology.

Required Equipment:

Each of the following pieces of equipment should be brought to all lectures & labs:

- Mechanical pencil Colored pencils
- Ruler with cm units or inch measured in tenths DO NOT buy a ruler that marks off 32^{nd} of inch.
- Protractor - A really good tool which combines a protractor and a good ruler in one is the C-Thru W-5 Standard/Metric Protractor Ruler 6" X 1.5"
- Tracing Paper (can use white copier paper)
- Textbook
- Calculator

Grading Policy (see below for description of individual categories):

Students are expected to keep track of their performance throughout the semester and seek guidance from available sources (including the instructor) if their performance drops below satisfactory levels. Grades will be determined quantitatively using the following formula. Final grades are not "curved" in this class.

- Exam I: 10%
- Exam II: 15%
- Final Exam: 15%

- Friday Quizzes: 5%
- Lab exercises/Problem Sets: 40% (Can drop lowest lab grade, with some exceptions)
- Lab Quizzes: 5%
- Field Trip: 5%
- Presentations & Participation: 5%

Late Policy:

For Problem Sets & Field Trip Report, one letter grade off for each academic day late. Presentations will be counted as zero if not ready on assigned date.

Grade Grievances: Any appeal of a grade in this course must follow the procedures and deadlines for grade-related grievances as published in the current University Catalog.

Attendance:

At The University of Texas at Arlington, taking attendance is not required. Rather, each faculty member is free to develop his or her own methods of evaluating students' academic performance, which includes establishing course-specific policies on attendance. As the instructor of this section, I have established the following policy: ***Attendance in lab is mandatory. Lack of attendance without prior approval will result in a zero for that lab assignment. Attendance in lecture is up to you, but if you miss class, you are responsible for learning the material. I will not take extra time to teach you things you should have learned by coming to class.***

Labs:

Laboratory exercises and associated problem sets constitute the largest part of your grade. This reflects the importance I place on them, the time I expect, on average, you will need to spend on them, and the care with which you will complete them. Generally, the in-class portion of the lab will be part of what you turn in. Occasionally, additional problems related to lecture material may be assigned as part of the weekly problem set. All lab/ problem set assignments are due at the beginning of class, one week from their assignment. Attendance in the lab section you are signed up for is mandatory. Failure to show without making prior arrangements will result in a zero for that lab. If you are more than 15 minutes late you will be counted as absent. You may drop your lowest lab/problem set score, except for Labs 5 and 11, which are un-droppable. Also, while you may not "switch" lab sections at your convenience, you may, if you wish, attend both lab sections to reinforce material. Lab materials will be allocated preferentially to student attending their assigned section, however.

Lab Quizzes:

In lieu of a lab final at the end of the semester, there will be lab quizzes starting in the third lab period. Each quiz will focus on material from two labs prior; however the quizzes will be cumulative. For example, in lab three, the quiz will focus on lab one. In lab four, the quiz will focus on lab two, but some material from lab one may show up. No quiz will be given for the final lab of the semester.

Exams: There are three in-class exams in this class (in addition to the lab final). The first will cover material through October 1st, the second will cover material through November 5th, and the final exam will cover everything. Please note that the second and final exam will be cumulative. Structural geology is like math, the stuff you do in the beginning is a building block for the stuff you do later.

Friday Quizzes

Quizzes will be given on Fridays throughout the semester specifically on the material covered during the corresponding week, including all reading for the week. These will consist of a few very simple questions, the goal of which is to demonstrate you have done the reading and have internalized information covered in class. Like the labs, you may drop your lowest quiz score.

Presentations:

Instead of a final project, students will present, IN GROUPS OF TWO or THREE, a PowerPoint-based presentation and lead a discussion related to a paper from the literature in class. These presentations will be on pre-determined technical papers selected from the structural geology literature (see list below), and they will be scattered throughout the semester as indicated in the course schedule (next page). The papers are listed below, and the dates they will be presented have been chosen because the papers are directly related to the material we are covering in the class at those times. The purpose of these presentations is threefold: (1) to supplement course material; (2) to give you a break from listening to me; (3) to give you a chance to see what real structural geology research is being done beyond the classroom; and (4) to give you experience giving technical presentations to your peers. Presenters will be expected to provide adequate **background** for the audience to understand what **questions/hypotheses** the authors are trying to address, adequate description of the **methods** the authors used, the **results** that the authors report, and an adequate **discussion/synthesis** of the results. Typically, I would expect a presentation should last 15 minutes, with at least 5 minutes of background material. After the presentation, presenters should be prepared to guide a ~10 minute discussion. A good way to do this may be to end the presentation with a series of "guiding questions" highlighting some of the important points of the paper.

Presenters will be provided with a *Dropbox* folder containing some helpful information pertinent to their paper, including a set of guiding questions intended to help them focus on the main points of the paper while reading the paper and making the presentation. **Presenters are also strongly encouraged to meet with the instructor at least one week before your presentation to go through important concepts that should be covered. YOU SHOULD SIGN UP FOR YOUR PAPER ON BLACKBOARD within the first two weeks of class.** Presenters should have already read the paper before this meeting. It is up to presenters to schedule this meeting with the instructor.

All students are expected to read each paper, and will be held responsible for the main points on exams. Part of your grade is to participate in each discussion by asking questions, making comments, etc. **Please note the papers are not necessarily in the correct order on Blackboard.**

Paper 1: Shaw, J. H. and P. M. Shearer (1999), An elusive blind thrust beneath metropolitan Los Angeles, *Science*, 283, 1516.

Paper 2: Segall, P., and D. D. Pollard (1983), Nucleation and Growth of Strike Slip Faults in Granite, *Journal of Geophysical Research*, 88(B1), 555–568.

Paper 3: Booth, S. L. (1982). Structural analysis of portions of the Washita Valley fault zone, Arbuckle Mountains, Oklahoma, *The Shale Shaker Digest*, 31-44.

Paper 4: Bergbauer, S., & Pollard, D. D. (2004). A new conceptual fold-fracture model including prefolding joints, based on the Emigrant Gap anticline, Wyoming. *Geological Society of America Bulletin*, *116*(3-4), 294-307.

Paper 5: Hossain, K.M. (1979), Determination of strain from stretched belemnites, *Tectonophysics*, 60, p. 279-288.

Paper 6: Byerlee, J. (1978), Friction in rocks, *Pure and Applied Geophysics*, 116, p. 615-626.

Paper 7: Di Toro, G., R. Han, T. Hirose, N. De Paola, S. Nielsen, K. Mizoguchi, F. Ferri, M. Cocco, and T. Shimamoto (2011), Fault lubrication during earthquakes, *Nature*, v. 471, p. 494-499.

Paper 8: Secor, D.T. (1965) Role of fluid pressure in jointing, American Journal of Science, v. 263, p. 633-646.

Paper 9: Maerten, L., P. Gillespie, and D.D. Pollard (2002), Effects of local stress perturbation on secondary fault development, *Journal of Structural Geology*, v. 24, p. 145-153.

Paper 10: Del Castello, M. and M.L. Cooke (2008), Watch faults grow before your very eyes in a deformational sandbox, Journal of Geoscience Education, 56, 324-333.

Paper 11: Hirth, G. and J. Tullis (1994), The brittle-plastic transition in experimentally deformed quartz aggregates, *Journal of Geophysical Research*, v. 99, p. 11,731-11,747

Paper 12: Scholz, C. H. (1988). The brittle-plastic transition and the depth of seismic faulting. *Geologische Rundschau*, *77*(1), 319-328.

Paper 13: Griffith, W. A., S. Nielsen, G. Di Toro, and S.A.F. Smith (2010), Rough faults, distributed weakening, and off-fault deformation, *Journal of Geophysical Research*, v. 115, DOI: 10.1029/2009JB006925.

Field Trip:

There will be a MANDATORY 1-day field trip to the Arbuckle Mountains tentatively scheduled **Saturday October 3-Sunday October 4**. The field trip is critical, since there is very little structural geology to be observed in the immediate DFW area. The material covered in the field trip will be fair game for the final exam. There will be a slightly less attractive alternative for students who have unsurmountable obstacles to attending. **YOU MUST SIGN UP FOR THE FIELDTRIP OR THE ALTERNATIVE on Blackboard by September 7!**

Drop Policy: Students may drop or swap (adding and dropping a class concurrently) classes through self-service in MyMav from the beginning of the registration period through the late

registration period. After the late registration period, students must see their academic advisor to drop a class or withdraw. Undeclared students must see an advisor in the University Advising Center. Drops can continue through a point two-thirds of the way through the term or session. It is the student's responsibility to officially withdraw if they do not plan to attend after registering. **Students will not be automatically dropped for non-attendance**. Repayment of certain types of financial aid administered through the University may be required as the result of dropping classes or withdrawing. For more information, contact the Office of Financial Aid and Scholarships (http://wweb.uta.edu/aao/fao/).

Americans with Disabilities Act: The University of Texas at Arlington is on record as being committed to both the spirit and letter of all federal equal opportunity legislation, including the Americans with Disabilities Act (ADA). All instructors at UT Arlington are required by law to provide "reasonable accommodations" to students with disabilities, so as not to discriminate on the basis of that disability. Any student requiring an accommodation for this course must provide the instructor with official documentation in the form of a letter certified by the staff in the Office for Students with Disabilities, University Hall 102. Only those students who have officially documented a need for an accommodation will have their request honored. Information regarding diagnostic criteria and policies for obtaining disability-based academic accommodations can be found at www.uta.edu/disability or by calling the Office for Students with Disabilities at (817) 272-3364.

Title IX: The University of Texas at Arlington is committed to upholding U.S. Federal Law "Title IX" such that no member of the UT Arlington community shall, on the basis of sex, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity. For more information, visit www.uta.edu/titleIX.

Academic Integrity: Students enrolled all UT Arlington courses are expected to adhere to the UT Arlington Honor Code:

> *I pledge, on my honor, to uphold UT Arlington's tradition of academic integrity, a tradition that values hard work and honest effort in the pursuit of academic excellence.*
>
> *I promise that I will submit only work that I personally create or contribute to group collaborations, and I will appropriately reference any work from other sources. I will follow the highest standards of integrity and uphold the spirit of the Honor Code.*

UT Arlington faculty members may employ the Honor Code as they see fit in their courses, including (but not limited to) having students acknowledge the honor code as part of an examination or requiring students to incorporate the honor code into any work submitted. Per UT System *Regents' Rule* 50101, §2.2, suspected violations of university's standards for academic integrity (including the Honor Code) will be referred to the Office of Student Conduct. Violators will be disciplined in accordance with University policy, which may result in the student's suspension or expulsion from the University.

Student Support Services: UT Arlington provides a variety of resources and programs designed to help students develop academic skills, deal with personal situations, and better understand concepts and information related to their courses. Resources include tutoring, major-based learning centers, developmental education, advising and mentoring, personal counseling, and federally funded programs. For individualized referrals, students may contact the Maverick Resource Hotline by calling 817-272-6107, sending a message to resources@uta.edu, or visiting www.uta.edu/resources.

Lab Safety Training: Students registered for this course must complete all required lab safety training prior to entering the lab and undertaking any activities. Once completed, Lab Safety Training is valid for the remainder of the same academic year (i.e., through the following August) and must be completed anew in subsequent years. There are no exceptions to this University policy. Failure to complete the required training will preclude participation in any lab activities, including those for which a grade is assigned.

Electronic Communication: UT Arlington has adopted MavMail as its official means to communicate with students about important deadlines and events, as well as to transact university-related business regarding financial aid, tuition, grades, graduation, etc. All students are assigned a MavMail account and are responsible for checking the inbox regularly. There is no additional charge to students for using this account, which remains active even after graduation. Information about activating and using MavMail is available at http://www.uta.edu/oit/cs/email/mavmail.php.

Student Feedback Survey: At the end of each term, students enrolled in classes categorized as "lecture," "seminar," or "laboratory" shall be directed to complete an online Student Feedback Survey (SFS). Instructions on how to access the SFS for this course will be sent directly to each student through MavMail approximately 10 days before the end of the term. Each student's feedback enters the SFS database anonymously and is aggregated with that of other students enrolled in the course. UT Arlington's effort to solicit, gather, tabulate, and publish student feedback is required by state law; students are strongly urged to participate. For more information, visit http://www.uta.edu/sfs.

Final Review Week: A period of five class days prior to the first day of final examinations in the long sessions shall be designated as Final Review Week. The purpose of this week is to allow students sufficient time to prepare for final examinations. During this week, there shall be no scheduled activities such as required field trips or performances; and no instructor shall assign any themes, research problems or exercises of similar scope that have a completion date during or following this week unless specified in the class syllabus. During Final Review Week, an instructor shall not give any examinations constituting 10% or more of the final grade, except makeup tests and laboratory examinations. In addition, no instructor shall give any portion of the final examination during Final Review Week. During this week, classes are held as scheduled. In addition, instructors are not required to limit content to topics that have been previously covered; they may introduce new concepts as appropriate.

Other Suggested Texts:

As a general rule, I advise students to avoid the use of internet search engines for completing exercises in this course. This is for two reasons. First, beyond scholarly articles and textbooks, most information on the web is NOT peer-reviewed. There is no guarantee that the information you are looking at is correct. Second, even if the information you are looking at is valid, terminology and related methods vary significantly in different places. Students in the past have found themselves extremely confused, for example, by watching YouTube videos of nice British ladies showing them how to solve structural geology problems. If you need a different perspective on something I cover in class, or if you are simply interested, please try one of the following texts instead of Google:

- Davis, G. H. and Reynolds, S. J., 1996. *Structural Geology of Rocks and Regions* (the easiest to read structural geology book)
- Twiss and Moores, *Structural Geology* (the most complete structural geology book)
- Allmendinger, Cardozo, and Fischer, *Structural Geology Algorithms: Vectors and Tensors*
- Jaeger, J., Cook, N., and Zimmerman, *Fundamentals of Rock Mechanics*
- Lisle and Leyshon, *Stereographic Projection Techniques for Geologists and Civil Engineers*
- Means, W.D., *Stress and Strain, Basic Concepts of Continuum Mechanics for Geologists*
- Park, R. G., *Foundations of Structural Geology*
- Passchier and Trouw, *Microtectonics*
- Pollard and Fletcher, *Fundamentals of Structural Geology*
- Ramsay and Huber, *The Techniques of Modern Structural Geology, Volume 1: Folds and Fractures*
  Ramsay and Huber, *The Techniques of Modern Structural Geology, Volume 2: Strain Analysis*
- Turcotte and Schubert, *Geodynamics*

GEOL 3443: Structural Geology Course Schedule Fall 2015

Lecture Schedule:

*Book Abbreviations: Fossen(F), Marshak & Mitra (M&M), Pollard & Martel (P&M)

Date	Topic	Associated Reading
28-Aug	Introduction - Logistics, types of structural data	F: p. 1-13
31-Aug	Introduction - Descriptive, Kinematic, Dynamic Analysis	F: p. 14-19, P&M: Chp 1 p. 1-15
2-Sep	Stereographic Projections	F. p. 422-427
4-Sep	Linear and Planar Fabrics	F. p. 244-252, p. 259-264
7-Sep	No Class – Labor Day	
9-Sep	Geologic Mapping Basics	M&M: p. 387-398
11-Sep	Fractures	F: p. 119-124
14-Sep	Faults	F: p. 151-165, p. 190-192
16-Sep	**Paper 1 Presentation** & Geologic Mapping Basics continued	**Shaw et al., *Science*, 1999**
18-Sep	Brittle deformation mechanisms and other types of fractures	F: p. 120-124, p. 142-145
21-Sep	**Paper 2 Presentation & Paper 3 Presentation**	**Segall & Pollard JGR, 1983; Booth, 1982)**
23-Sep	Folds I	F: p. 219-226
25-Sep	**Paper 4 Presentation** & Fold-related fractures	**Bergbauer & Pollard *JSG*, 2004**
28-Sep	Folds II	F: p. 226-239
30-Sep	Scalars, Vectors, & Matrices	P&M: Chp. 2 p. 1-41 & Chp. 3, p. 3-6
2-Oct	Basic Matrix-Vector manipulation	P&M: Chp. 2 p. 43-52
5-Oct	Coordinate Transformations	P&M: Chp 2 p. 49-52
7-Oct	**EXAM I**	
9-Oct	Deformation and Strain in one and two dimensions	F. p. 21-29
12-Oct	Strain Ellipsoid & Types of strain	F. p. 30-38, p. 41-43
14-Oct	**Paper 5 presentation**	**Hossain, *Tectonophysics*, 1979**
16-Oct	Deformation history from deformed rocks	F. p. 43-48, p. 56-61
19-Oct	Stress on a surface (and how it is different than a force)	F. p. 68-72
21-Oct	State of stress at a point/the stress tensor	F. p. 72-75; P&M Chp. 4, p. 1-20
23-Oct	Principal Stress & The Mohr Circle	F. p. 75-76
26-Oct	Rock Strength and Friction	F. p. 124-141, 165-178
28-Oct	Measures of Stress in the Crust	F., p. 80-82
30-Oct	**Paper 6 & Paper 7 Presentation**	**Byerlee, *Pageoph*, 1978 & Di Toro et al., *Nature*, 2011**
2-Nov	NO CLASS – GSA Meeting	
4-Nov	NO CLASS – GSA Meeting **LAST DAY TO DROP CLASSSES**	

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6-Nov	Stress Transformations	P&M Chp. 3 p. 49-52
9-Nov	**EXAM 2**	
11-Nov	**Paper 8 & Paper 9 Presentation**;	**Secor, AJS, 1965; Maerten et al.,**
13-Nov	Elastic Constitutive Behavior	P&M Chp. 4, p. 48-56
16-Nov	Stress in the elastic-brittle crust	F. p. 83-92
18-Nov	Other constitutive laws and tectonic implications I	F. p. 103-115
20-Nov	Other constitutive laws and tectonic implications II	F. p. 103-115
23-Nov	**Paper presentations 10**	**DelCastello et al., 2008**
25-Nov	No Class: Thanksgiving Holiday	
27-Nov	No Class: Thanksgiving Holiday	
30-Nov	Ductile Deformation & Fabric Development	F. p. 244-268
2-Dec	**Paper 11 & 12 presentation**	**Hirth and Tullis, JGR, 1994, Scholz, 1988**
4-Dec	Ductile Deformation, continued	F. p. 286-292, 297-303
7-Dec	**Paper 13 Presentation,**	**Griffith et al., JGR, 2010,**
9-Dec	Bringing it all together: A roadmap for structural analyses,	Excerpt from Pollard & Fletcher, 2005
16-Dec	Final Exam, regular classroom, 8AM-11:30AM	**Everything**

GEOL 3443: Structural Geology **Fall 2015**

Lab Schedule:

Date	Topic	Associated Reading
Week 1 (27-28 Aug)	No Lab – Only Thursday & Friday Classes held this week	
Week 2 (31 Aug-4 Sep)	Lab 1: Measurements of Geologic Structures & Fabrics (Due week of Lab 2)	M&M: Chp 1 p. 1-14
Week 3 (7-11 Sep)	No Lab – Labor Day Week (no class on Monday)	
Week 4 (14-18 Sep)	Lab 2: Geologic Contacts in Maps and Cross-Sections (Lab 1 Due today)	M&M: Chp. 2 p. 19-34 M&M: Chp. 3 p. 45-47
Week5 (21-25 Sep)	Lab 3: More Fun with Geologic Maps	M&M: Chp. 3 p. 47-54 M&M: Chp. 5 p. 95-100
Week 6 (28 Sep-2 Oct)	Lab 4: Faults & Folds in Geologic Maps	M&M: Chp. 4 p. 81-83 M&M: Chp. 5 p. 105-109 M&M: Chp. 6 p. 155-162
Week 7 (5 – 9 Oct)	Lab 5: Advanced Geologic Map Analysis	M&M: p. 269-281, p. 284-291
Week 8 (12-16 Oct)	Lab 6: Introduction to MATLAB (Due week of Lab 6)	Lab 6 Handout
Week 8 (19-23 Oct)	Lab 7: Coordinate transformations (Lab 6 Due	Lab 7 Handout P&M: Chp 2 p. 49-52
Week 9 (26-30 Oct)	Lab 8: Strain Analysis	Lab 8 Handout P&M Chp 5, p. 16-24
Week 10 (2-6 Nov)	No Lab – Geological Society of America Meeting	
Week 11 (9-13 Nov)	Lab 9: Stress Analysis: Mohr Circle & Tensors	Lab 9 Handout M&M: Chp. 10 (all)
Week 12 (16-20 Nov)	Lab 10: Laboratory Rock Mechanics & Elasticity (GRC)	Lab 10 Handout M&M: Chp. 10 (all) – same reading as previous week
Week 13 (23-27 Nov)	No Lab – Thanksgiving Holiday	
Week 14 (30 Nov-4 Dec)	Lab 11: Elastic Models of Dikes	Lab 11 Handout
Week 15 (7 -9 Dec)	No Lab – Last week of classes	