



Department of Geological Sciences

Structural Geology GEOL2440

Fall 2017

On March 11, 2011, built up elastic strain, produced by compressive stresses of plate motion, was suddenly released along a portion of a thrust fault marking the boundary between the Pacific and North American plates off the east coast of Honshu, Japan. The Honshu Earthquake caused almost 21,000 deaths, displaced hundreds of thousands and destroyed or damaged many buildings, bridges and railways in local towns. These forces have a profound effect on us by deforming rocks into folds and faults, creating mountain ranges and making ocean basins. But there are many more reasons to be interested in deformation: hydrocarbons and metals are concentrated in structural traps created by folds and faults, rock mass strength is critical to engineered projects such as tunnels, bridges or foundations, and cracks in rocks increase permeability for groundwater and contaminants.

The objective of this course is to introduce you to (1) the character, geometry and map distribution of folds, faults and other associated structures; and (2) the stress and strain conditions responsible for the development of these structures. You will be introduced to mechanical principles necessary to understand and analyze rock deformation as well as classical descriptions and classification. From these basic principles you should be able to understand the processes and stress conditions that lead to rocks breaking at different angles under different conditions whether they occurred recently or millions of years ago. You should be able to describe the strain conditions necessary to produce a variety of different geologic features formed during a single deformation event. You should be able to use a geologic map and interpret deformation in four dimensions by clearly defining the relationship between fold and fault geometry, unconformities, and stratigraphic sequences.

We will start by introducing the course and primary geologic structures. After we have some idea of what we are in for, we will discuss the mechanical principles underpinning the formation of structures. With this background we will describe structures and be able to understand why they form. In lab you will learn practical techniques, mostly graphical, for how to describe structures whereas lectures give a broader, more theoretical approach. A daylong field trip in late September will provide an exceptional opportunity to see structures “in the wild” rather than crude blackboard sketches and static photographs.

Instructor: Jeff Young, Room 333 Wallace Building
phone: 204-474-8863
e-mail: jeff.young@umanitoba.ca
course website: <http://universityofmanitoba.desire2learn.com/>

Lectures: Tuesday and Thursday, 11:30 a.m. to 12:45 p.m., Room 218 Wallace Building

Labs: Tuesday, 2:30 to 5:25 p.m., Room 245 Wallace Building

Field Trip: Saturday, September 30, (8:00 to 5:00 p.m.)—*to be confirmed*. You should make every effort to participate. You will learn more in one day in the field than in a month of lectures.

My Availability: I am available for help most days except Tuesday. I accept no questions on Tuesdays. If my office door is open you are welcome to ask me questions. Please check the schedule on my office door or the course website. If necessary, make arrangements with me after class or call me (phone or e-mail) for an appointment.

No problem is too small.

Communication

All email communication must conform to the University of Manitoba “Communicating with Students” policy (<http://crscalprod1.cc.umanitoba.ca/Catalog/ViewCatalog.aspx?pageid=viewcatalog&catalogid=260&chapterid=2795&topicgroupid=15798>). You are required to obtain and use your UofM email account for all communication between yourself and the university.

When sending me an email I expect the subject line to contain the course name or number. The email **must** start with “Hello Jeff” or “Dear Jeff”. The email **must** end with your name and student number.

Although I may be connected in the evening or on weekends, I reserve this time for course development, outreach and research. Therefore, I may not respond until the following “business” day. Any questions related to the course content will be dealt with during the following class. I will read your question to the class, but I do not identify the sender. We all benefit from your participation.

I typically arrive soon after the previous class has finished. I need a few minutes to log into the computer system and setup for the class. Once I am finished setup you are welcome to ask questions. I also accept questions after class, but because there will may be a class following us I ask that we deal with these questions outside the lecture hall.

Recommended Text: Fossen, H., *Structural Geology 2nd ed.* Cambridge University Press, 2016.

Textbooks are reference sources that help us gain an understanding of concepts using learning strategies that are different from lectures. *Structural Geology* is the recommended textbook because of it has a relatively simple writing approach, a significant component on mechanics, good graphics and colour presentation. I do not specifically reference the textbook during class although some of the images that I will be using come from the textbook. This textbook will also be of use in *Structure and Metamorphism* (GEOL 3440). Other textbooks can be used if you prefer. Four commonly used texts are listed below.

- **Structural Geology of Rocks and Regions** 2nd ed. by Davis and Reynolds – This book was the course textbook for over 15 years. It is a good descriptive textbook in structural geology and the appendices are particularly good for field techniques. Unfortunately, it is relatively light on the mechanics of structural geology.
- **Earth Structure** 2nd ed. by Van Der Pluijm & Marshak — This book is a great addition to the list of structural geology textbooks. It is very readable and student friendly. This textbook covers structural geology within a tectonic framework and therefore its organization is different from Fossen or Davis and Reynolds.
- **Structural Geology** 2nd ed. by Twiss & Moores — This book is stronger on the mechanics of structural geology than Fossen, Davis & Reynolds or Van Der Pluijm & Marshak. Twiss and Moores have a very comprehensive treatment of the topic of structural geology (including the descriptive aspects). The writing style is much “drier” than the previous two textbooks.
- **Fundamentals of Structural Geology** by Pollard & Fletcher — This book is not for the student that has difficulty applying mathematical concepts to rock deformation. As a senior level textbook it is a necessary step for all modern, quantitative, structural geologists. This textbook focuses on the mechanics of structural geology. It includes minimal descriptive material, which is an integral part of this course (and most other introductory structural geology courses).

Evaluation Procedure:

40%	Lab Assignments
30%	Final Lab Examination (based on lab & map assignments - 3 hrs.)
30%	Final Lecture Examination (based on lectures - 2 hrs.)

Grades are assigned based on the distribution of marks at the end of the course. Some students describe this style of grading as “on a curve”. Grading on a curve is done to ensure a fair and reasonable distribution of grades between sections and years.

Honesty Declaration

All students taking courses offered by the Department of Geological Sciences must read, sign and submit the honesty declaration to the instructor.

Lectures

Lectures are 75 minutes long and consist of theory and map instruction sessions. The following is a list of topics that are planned for the lecture portion of the course. Notes based on the various topics were developed for my use, but you are more than welcome to use them. The notes may help you learn, but do not expect the notes to replace active attendance and participation in class. Append additional information to your notes.

Using this outline you should consider reading ahead in the textbook.

1. *Introduction to structural geology*: classifying structures, maps, primary / non-tectonic structures and unconformities
2. *Deformation of geologic materials and their behaviour*: an introduction to force, stress, deformation and strain
3. *Brittle deformation*: tensile cracking and shear fractures, joint and vein sets and systems
4. *Faults*: fault nomenclature, net slip, apparent movement, classification systems; normal faults, thrust faults, strike slip faults; repetition and omission of strata; fault plane features and physiographic features associated with faulting.
5. *Ductile deformation*: simple shear, pure shear; homogenous and heterogenous deformation, processes and microstructures including factors affecting deformational behaviour.
6. *Folds*: fold nomenclature, classification based on closure, symmetry, orientation and style; mechanisms of folding; small-scale structures associated with folds; fold systems; introduction to polyphase folding.
7. *Planar fabrics*: penetrative cleavage, spaced cleavage, microlithons; schistosity, slaty cleavage, fracture cleavage, strain slip cleavage, pressure solution cleavage; cleavage refraction; relationship to other structures.
8. *Linear fabrics*: mineral lineations, mineral aggregate lineations, s-intersection lineations, crenulation lineations, fold axis lineations, boudinage, relationship to other structures.

Miscellaneous Map Problems and Exercises

The expression and interpretation of geological structures on maps and cross sections are important components of any course in structural geology. We will deal with these components through a series of map interpretation exercises that will be introduced and reviewed in lecture. Each interpretation requires the preparation of a cross section and interpretation of a geologic history. Students are responsible for completing these exercises, but no marks will be assigned. Students are welcome to discuss the exercises with the instructor. Material covered by the map exercises **will be** part of the *final lab exam*.

Lecture Equipment

I suggest students bring the following equipment to all lectures.

1. Pens and pencils
2. Eraser – good quality
3. Ruler – metric and imperial measurement
4. Calculator with trigonometric function
5. Several colouring pencils for labeling
6. Paper for note taking and graph paper for geologic cross sections
7. Class notes and handouts

Laboratory

Laboratories are an extremely important part of all geoscience courses. Structural Geology is no exception. You just have look at the mark allocation to realize the importance of the lab (40% assignments + 30% final lab exam = 70% of course mark). The lab will deal with concepts of three-dimensional geometry. We will develop graphical techniques that are separate from and overlap with lecture concepts. There is a strong correlation between lab assignments and miscellaneous assignments.

The laboratory sessions will be three hours. There will be 13 lab sessions starting Tuesday, September 12th and ending Tuesday, December 5th. Labs will consist of an instructional session (with handouts) followed by an assignment. The instructional session will introduce concepts necessary to complete the assignment and review examples.

Some assignments or parts of assignments may be due before leaving the lab. Otherwise assignments are due at the **beginning** of the following lab. Marks will be deducted for any late assignments and may not be accepted. Assignments will be graded and returned, usually the following week. All lab questions are equally weighted. The following is a list of topics that are planned for the weekly laboratory portion of the course.

1. Introduction to descriptive geometry and the orientation of planar and linear geologic features. Definition of strike (strike lines), true dip (true dip line), apparent dip (apparent dip lines) of planar features; plunge and pitch of linear features.
2. Orthographic projections and trigonometric analysis of planar and linear features
3. Orthographic projections and map problems
4. Analysis of geologic maps: unconformities and faults
5. Stereographic projections: plotting orientation data for planar and linear structures on stereonet
6. Stereographic projections: stereographic poles, analysis of fold structures and true thickness
7. Stereographic projections: rotational fault and unconformity problems
8. Translational fault problems: applications of orthographic and stereographic methods
9. Drill hole problems
10. Stereographic projections: orientation of principal stresses
11. Analysis of geologic maps: outcrop patterns produced by faulted and folded sequences
12. Analysis of geologic maps: outcrop patterns produced by unconformities and faulted and folded sequences

Laboratory Equipment:

Students **must** bring the following lab equipment to all labs.

1. Selection of pencils: 2H and 4H (*Note*: HB and softer pencils are unacceptable for orthographic and stereographic projections)
2. Eraser – good quality
3. Ruler – metric and imperial measurements
3. Set of triangles (30-60° and 45° – minimum 8 inch)
4. One navigational protractor or 6-inch protractor – the navigational protractor is available from Semira Alekic in Room 240 Wallace
5. Calculator with trigonometric functions
6. Several coloured pencils for labeling projections
7. Paper for note taking and graph paper for geologic cross sections

The following lab equipment will be needed for labs dealing with stereographic projections only:

1. Tracing paper or onion skin paper - 8.5" x 11"
2. Scotch tape
3. Flat head tack

Note: I will supply you with one (*and only one*) flat head tack.

Additional Lab Notes:

1. Students are encouraged to work together, but lab assignments are individual efforts and the final products **must** reflect that individuality.

2. Assignments that are submitted must be neat and accurate. Marks will be deducted for poorly constructed and messy answers.

Student Accessibility Services (SAS)

If you are student with accessibility concerns please contact SAS for academic accommodation supports and services such as note-taking, interpreting, assistive technology and exam accommodations. Contact SAS to arrange a confidential consultation at:

Student Accessibility Services
520 University Centre
204-474-7423 / student_accessibility@umanitoba.ca
URL: umanitoba.ca/student/saa/accessibility/

Once you are registered with SAS please contact me about one week prior to the final examinations to ensure that arrangements have been made.

Technology

Various technologies are commonly used to help us learn, but they do not replace active participation. Active participation ranges from silent note-taking to engagement in class discussions. The following rules regarding technology are used in this course:

- No audio or video recording of lectures or presentations is allowed in any format, openly or surreptitiously, in whole or in part without permission of the instructor of this course, Jeff Young. Course materials (both paper and digital) are for the student's private study and research.
- Use of electronic equipment by students, other than calculators, is prohibited during lecture or lab.
- No computer technology: course notes are available on a USB stick that hangs on my office door. Notes will be loaded onto the USB stick at least one day before class although there may be some changes to the notes before they are presented in class.
- Phones should be on vibrate mode during class. If a student is on call for an emergency situation, please leave the classroom before using it.

Field Trip

“Graduating geologists who have trained without the benefit of extensive geological fieldwork is like training doctors without ever allowing them to dissect a cadaver”
Mark Cooper (Vice-President, Encana Corp, 2007)

The course field trip will be held on Saturday, September 30. We will leave Wallace Building at 8:00 a.m. and return to the Wallace Building at about 5:00 p.m.. We will travel in a large touring bus to the Whiteshell Provincial Park. We will spend the morning and part of the afternoon in the park examining a number of outcrop locations where we will discuss the geology. In the afternoon we will travel along Highway 17 to visit a number of outcrops in northwestern Ontario. At about 3:00 p.m. we will start our return home.

You are responsible to bring your own food and water for the day. We will not be stopping at any stores, restaurants, etc. You will also have to be prepared for the weather. I recommend that you bring a good pair of “shoes/boots” to climb on the rocks, etc.

On the bus you will receive a field trip guidebook describing the various locations and some of the regional geology. I recommend that you bring a pen/pencil, ruler and camera. This field trip will probably be the start of your geology photo library.

You are required to submit a signed release form, which I will distribute by Tuesday, September 19th.

General Information

1. Students are advised to read the General Academic Regulations and University Policies published as part of the Academic Calendar & Catalog on the University of Manitoba website. In particular, students should be aware of the policies regarding academic dishonesty, personation at tests/examinations and plagiarism and cheating. The URL for the web site hosting this information is

<http://crscalprod1.cc.umanitoba.ca/Catalog/ViewCatalog.aspx?pageid=viewcatalog&loaduserredits=False>

2. Performance on the lab assignments constitutes written evaluative feedback prior to the voluntary withdrawal deadline. ***The last date for voluntary withdrawal without academic penalty is Friday, November 17th, 2017.***

3. The academic schedule published as part of the Academic Calendar & Catalog on the University of Manitoba website indicates the examination period for this academic session is December 11th to 21st. It is each student's responsibility to remain available during the entire examination period. Students unable to write a final examination must file an application for a deferred examination with their own faculty.

Supplementary Information – Schedule “A”

Section (a): A list of academic supports available to Students, such as the Academic Learning Centre, Libraries, and other supports as may be appropriate:

Writing and Learning Support

The Academic Learning Centre (ALC) offers services that may be helpful to you throughout your academic program. Through the ALC, you can meet with a learning specialist to discuss concerns such as time management, learning strategies, and test-taking strategies. The ALC also offers peer supported study groups called Supplemental Instruction (SI) for certain courses that students have typically found difficult. In these study groups, students have opportunities to ask questions, compare notes, discuss content, solve practice problems, and develop new study strategies in a group-learning format.

You can also meet one-to-one with a writing tutor who can give you feedback at any stage of the writing process, whether you are just beginning to work on a written assignment or already have a draft. If you are interested in meeting with a writing tutor, reserve your appointment two to three days in advance of the time you would like to meet. Also, plan to meet with a writing tutor a few days before your paper is due so that you have time to work with the tutor's feedback.

These Academic Learning Centre services are free for U of M students. For more information, please visit the Academic Learning Centre website at:

<http://umanitoba.ca/student/academiclearning/>. You can also contact the Academic Learning Centre by calling 204-480-1481 or by visiting 201 Tier Building.

University of Manitoba Libraries (UML)

As the primary contact for all research needs, your liaison librarian can play a vital role when completing academic papers and assignments. Liaisons can answer questions about managing citations, or locating appropriate resources, and will address any other concerns you may have, regarding the research process. Liaisons can be contacted by email or phone, and are also available to meet with you in-person. A complete list of liaison librarians can be found by subject: <http://bit.ly/WcEbA1> or name: <http://bit.ly/1tJObB4>. In addition, general library assistance is provided in person at 19 University Libraries, located on both the Fort Garry and Bannatyne campuses, as well as in many Winnipeg hospitals. For a listing of all libraries, please consult the following: <http://bit.ly/1sXe6RA>. When working remotely, students can also receive help online, via the Ask-a-Librarian chat found on the Libraries' homepage: www.umanitoba.ca/libraries.

Section (b): A statement regarding mental health that includes referral information:

For 24/7 mental health support, contact the Mobile Crisis Service at 204-940-1781.

Student Counselling Centre

Contact SCC if you are concerned about any aspect of your mental health, including anxiety, stress, or depression, or for help with relationships or other life concerns. SCC offers crisis services as well as individual, couple, and group counselling. *Student Counselling Centre:*

<http://umanitoba.ca/student/counselling/index.html>

474 University Centre or S207 Medical Services

(204) 474-8592

Student Support Case Management

Contact the Student Support Case Management team if you are concerned about yourself or another student and don't know where to turn. SSCM helps connect students with on and off campus resources, provides safety planning, and offers other supports, including consultation, educational workshops, and referral to the STATIS threat assessment team.

Student Support Intake Assistant <http://umanitoba.ca/student/case-manager/index.html>

520 University Centre

(204) 474-7423

University Health Service

Contact UHS for any medical concerns, including mental health problems. UHS offers a full range of medical services to students, including psychiatric consultation.

University Health Service <http://umanitoba.ca/student/health/>

104 University Centre, Fort Garry Campus

(204) 474-8411 (Business hours or after hours/urgent calls)

Health and Wellness

Contact our Health and Wellness Educator if you are interested in information on a broad range of health topics, including physical and mental health concerns, alcohol and substance use harms, and sexual assault.

Health and Wellness Educator <http://umanitoba.ca/student/health-wellness/welcome.html>

Katie.Kutryk@umanitoba.ca

469 University Centre

(204) 295-9032

Live Well @ UofM

For comprehensive information about the full range of health and wellness resources available on campus, visit the Live Well @ UofM site:

<http://umanitoba.ca/student/livewell/index.html>

Section (c): A notice with respect to copyright:

All students are required to respect copyright as per Canada's *Copyright Act*. Staff and students play a key role in the University's copyright compliance as we balance user rights for educational purposes with the rights of content creators from around the world. The Copyright Office provides copyright resources and support for all members of the University of Manitoba community.

Visit <http://umanitoba.ca/copyright> for more information.

Section (d): A statement directing the student to University and Unit policies, procedures, and supplemental information available on-line:

Your rights and responsibilities

As a student of the University of Manitoba you have rights and responsibilities. It is important for you to know what you can expect from the University as a student and to understand what the

University expects from you. Become familiar with the policies and procedures of the University and the regulations that are specific to your faculty, college or school.

The [Academic Calendar](http://umanitoba.ca/student/records/academiccalendar.html) <http://umanitoba.ca/student/records/academiccalendar.html> is one important source of information. View the sections *University Policies and Procedures* and *General Academic Regulations*.

While all of the information contained in these two sections is important, the following information is highlighted.

- If you have questions about your grades, talk to your instructor. There is a process for term work and final **grade appeals**. Note that you have the right to access your final examination scripts. See the Registrar's Office website for more information including appeal deadline dates and the appeal form <http://umanitoba.ca/registrar/>
- You are expected to view the General Academic Regulation section within the Academic Calendar and specifically read the **Academic Integrity** regulation. Consult the course syllabus or ask your instructor for additional information about demonstrating academic integrity in your academic work. Visit the Academic Integrity Site for tools and support <http://umanitoba.ca/academicintegrity/> View the **Student Academic Misconduct** procedure for more information.
- The University is committed to a respectful work and learning environment. You have the right to be treated with respect and you are expected conduct yourself in an appropriate respectful manner. Policies governing behavior include the:

Respectful Work and Learning Environment

http://umanitoba.ca/admin/governance/governing_documents/community/230.html

Student Discipline

http://umanitoba.ca/admin/governance/governing_documents/students/student_discipline.html and,

Violent or Threatening Behaviour

http://umanitoba.ca/admin/governance/governing_documents/community/669.html

- If you experience **Sexual Assault** or know a member of the University community who has, it is important to know there is a policy that provides information about the supports available to those who disclose and outlines a process for reporting. The **Sexual Assault** policy may be found at:
http://umanitoba.ca/admin/governance/governing_documents/community/230.html More information and resources can be found by reviewing the Sexual Assault site <http://umanitoba.ca/student/sexual-assault/>
- For information about rights and responsibilities regarding **Intellectual Property** view the policy http://umanitoba.ca/admin/governance/media/Intellectual_Property_Policy_-_2013_10_01.pdf

For information on regulations that are specific to your academic program, read the section in the Academic Calendar and on the respective faculty/college/school web site <http://umanitoba.ca/faculties/>

Contact an **Academic Advisor** within our faculty/college or school for questions about your academic program and regulations <http://umanitoba.ca/academic-advisors/>

Student Advocacy

Contact Student Advocacy if you want to know more about your rights and responsibilities as a student, have questions about policies and procedures, and/or want support in dealing with academic or discipline concerns.

<http://umanitoba.ca/student/advocacy/>

520 University Centre

204 474 7423

student_advocacy@umanitoba.ca