COURSE OUTLINE: ES3002

Course Title	**Structural Geology and Tectonics**		
Course Code	**ES3002**		
Offered	Study Year 3, Semester 2		
Course Coordinator	Judith Hubbard (Asst Prof)	JHubbard@ntu.edu.sg	6592 7537
Pre-requisites	ES1003		
No of AUs	4		
Contact hours	Field Trip: 50, Lectures: 39, Laboratories: 39		
Last revised	12 Oct 2018, 08:29		

Course Aims

This course is designed to give you an understanding of the deformation of Earth materials, including mountain building and plate tectonics, faulting and earthquakes, folding, and ductile deformation.

Intended Learning Outcomes

Upon successfully completing this course, you should be able to:

1. Describe and draw the major types of fractures and folds, and explain what stresses are required to produce them.
2. Use a Mohr circle to analyze fault stresses and failure
3. Use a stereonet to plot different types of geological data and to solve problems by hand and on a computer, and explain why this is useful.
4. Interpret a geological map (on paper and in Gocad), and draw a realistic cross-section using quantitative fault-bend-folding techniques.
5. Perform a structural analysis of a remote sensing image, including extracting strike and dip data in Gocad and using that to draw a cross-section.
6. Plan, perform, and analyse an experiment to create an anolog fold-and-thrust belt.
7. Observe structural and rock data in the field and take notes in a field notebook.
8. Interpret a faulted outcrop and assess timing, style, and magnitude of deformation.
9. Write down the geological time scale
10. Research and present on an environmental issue

Course Content

Stress, strain, and rock strength

Fractures & faults

Fault-related folding

Ductile deformation

Tectonic regimes: compressional mountain belts, rift basins, strike-slip margins, passive margins

Assessment

Component	Course ILOs tested	ASE Graduate Attributes tested	Weighting	Team / Individual	Assessment Rubrics
Continuous Assessment					
Research Competency	1, 6, 10	**2.** a, b **4.** a, b **5.** c **8.** a, b **10.** a, b	4	team	See Appendix for rubric
Presentation	1, 6, 10	**2.** a, b **3.** b, c **4.** a, b **5.** c **8.** a, b **9.** b **10.** a, b	4	individual	See Appendix for rubric
Laboratories					
Assignment	1, 2, 3, 4, 5	**2.** a **3.** a **4.** a, b **5.** c **8.** a, b **10.** a	28	individual	See Appendix for rubric
Log Book	7, 8	**2.** b **3.** a, c **4.** a, b **5.** c **8.** a, b **10.** a	10	individual	See Appendix for rubric
Presentation	10	**2.** a, b **3.** a, b **4.** a **8.** a, b **9.** b	10	individual	See Appendix for rubric
Mid-semester Quiz					
Multiple Choice Questions	9	**8.** a	4	individual	
Short Answer Questions	1, 2, 3, 4	**3.** a **8.** a	40	individual	See Appendix for rubric
		Total	**100%**		

These are the relevant ASE Graduate Attributes.

2. Demonstrate intellectual flexibility and critical thinking

a. Demonstrate intellectual flexibility to view environmental issues from multiple perspectives

b. Question assumptions behind current ways of solving environmental problems

3. Demonstrate passion and use advanced communication skills to share that passion

a. Effectively communicate environmental concepts in writing

b. Effectively communicate environmental concepts in speech

c. Effectively communicate environmental concepts in various forms of media such as data visualisation, diagrams, animation, video, or podcasts

4. Formulate key scientific questions and develop hypotheses

a. Research and formulate questions involving environmental issues

b. Create and evaluate hypotheses to research such questions

5. Conduct research

c. Make first-hand observations in order to draw conclusions

8. Demonstrate the willingness and skills for lifelong learning

a. Demonstrate aptitude and enthusiasm to learn independently

b. Demonstrate good observation skills and a curiosity about the world

9. Demonstrate ethical values

b. Respect regulations involving plagiarism and copyright

10. Demonstrate collaboration and leadership skills

a. Learn collaboratively and be willing to share expertise with peers

b. Demonstrate leadership of small teams

Formative Feedback

Throughout the class, each lab will be returned to you 1-2 weeks after being turned in, with each component marked as correct or incorrect. The correct answers will be given. Cross sections and maps will have notes to indicate which parts are good and which parts could have been improved.

Quizzes will be graded and returned.

Your field notebook will be assessed holistically; overall suggestions and comments will be provided about good aspects of your notebook, and ways to improve, referring to specific pages in your field notebook as evidence. You will also receive verbal feedback after your field presentation.

Your video presentation of your research project (labs 9&10) will be discussed in class with feedback from both the professor and the students. You will receive advice during the course of the research project as well.

Learning and Teaching Approach

Field Trip (50 hours)	During the field trip, we will visit various outcrops and sites of interest. You will observe the geology independently and in groups. You will record your observations (qualitative and qualitative) in your field notebook and discuss with your fellow students and the teaching staff, and interpret how these observations fit into the tectonic context. During the trip you will also present on an environmental topic relevant to the area visited. You will create and use a 1-page handout as part of this presentation.
Lectures (39 hours)	Lectures will cover the various concepts in structural geology, and teach both ideas and techniques. Lectures will be primarily powerpoint or equivalent, with images, diagrams, and maps. During lectures you will also work on specific assignments to practice techniques explored in class. You will also evaluate specific rock samples.
Laboratories (39 hours)	In laboratories, you will use maps, cross sections, rock samples, analog models, and subsurface data to understand rock deformation. Some labs will take place in the computer lab using industry or research software and datasets; others will take place in the classroom and use analog modeling tools. You will perform calculations and interpret data to understand the stresses, strains, and rock deformation that have occurred in various places. Some of the laboratory work will take place during the three weekly hours of laboratory time with teaching staff available, but much will be done independently.

Reading and References

Recommended reading: "Earth Structure," by van der Pluijm and Marshak.

Students are also provided with a field trip guide which they are expected to read.

Course Policies and Student Responsibilities

Lab and field trip attendance are mandatory. Alternative assignments may be provided under

severe extenuating circumstances.

Midterms from previous years will be provided as study material.

You must turn in labs on time, at the beginning of the next week's class session. Any lab turned in more than 10 minutes after the start time of the class will be considered late. Late labs will be penalized at 10% per day (rounding up and including weekend days) unless special permission has been obtained in advance. You have 5 free late days to use at your discretion; these can be used either separately or together. Additional free late days will only be given under special circumstances.

You are encouraged to work together, but must complete and turn in your own work.

This is a 4 AU course. You should expect to spend on average 12 hours per week on this course, including lecture, labs, homework, reading, and studying.

Academic Integrity

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the Academic Integrity website for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

Instructor	Office Location	Phone	Email
Judith Hubbard (Asst Prof)	N2-01a-07	6592 7537	JHubbard@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course ILO	Readings/ Activities
1	Introduction to structural geology	1, 3, 8	Chapter 1
2	Structural geometry, geological maps, structural measurements	1, 4	Lab 1: Geological maps & structural measurements Strike & dip exercise
3	Strain, structural analysis of remote sensing images	1, 7, 9	Lab 2: Structural analysis of remote sensing images (includes timescale) Strain analysis exercise Chapter 4
4	Stress	2, 3, 9	Lab 3: Stereonets Possible pop quiz on time scale Chapter 3
5	Rock strength, natural stress measurements	1, 2, 3, 9	Lab 4: Natural stress measurements Mohr circle exercise Possible pop quiz on time scale Chapter 5
6	Fractures (joints), analysis of hand samples, field tools	1, 7, 9	Lab 5: Analysis of hand samples and introduction to field tools Possible pop quiz on time scale
7	Fractures (faults), seismic reflection method (2D)	1, 4, 9	Lab 6: Seismic reflection method in 2D Kink folding exercise Possible pop quiz on time scale
8	Field trip In-class test	1, 2, 3, 4, 8, 9, 10	3-6 day field trip to various geological outcrops. Includes presentation and field notes. In-class test
9	Ductile deformation	1, 4, 5, 9	Lab 7: Geological cross section 1 (analysis of satellite imagery to make a geological map) Imbricate folding exercise Possible pop quiz on time scale
10	Folds	1, 4, 9	Lab 8: Geological cross section 2 (analysis of geological map to make a cross section) Possible pop quiz on time scale
11	Fold & thrust belts	6, 8, 9	Lab 9: Analog fold-and-thrust belt (sandbox) Possible pop quiz on time scale
12	Normal fault settings	6, 8, 9, 10	Lab 9, continued Possible pop quiz on time scale
13	Class presentations In-class test	1, 2, 3, 6, 8, 9, 10	Lab 9, presentation In-class test

Appendix 1: Assessment Rubrics

Rubric for Continuous Assessment: Research Competency (4%)

You will work in groups of 2-3 to run and analyze analog fold-and-thrust belt models designed to fit

together as a classroom-wide experiment. These models will be analyzed in the small group and as a part of the suite of classroom models. You will create a short video that describes the experimental setup, the model results, and the analysis in the context of scientific understanding of fold and thrust belts.The video presentation itself is graded as a separate category.

Analysis: To receive a high mark, you must develop an appropriate experimental setup, run the experiment, and describe the main observables resulting from the experiment, as well as how these results fit into the classroom wide experiment and a more global understanding of fold and thrust belts.

To receive a passing mark, you must develop an appropriate experimental setup, run the experiment, and observe the main aspects of your results.You will receive a failing mark if you do not set up an appropriate experiment, or if you fail to run the experiment, or if you fail to analyze their experiment.

Rubric for Continuous Assessment: Presentation (4%)

You will work in groups of 2-3 to run and analyze analog fold-and-thrust belt models designed to fit together as a classroom-wide experiment. These models will be analyzed in the small group and as a part of the suite of classroom models. You will create a short video that describes the experimental setup, the model results, and the analysis in the context of scientific understanding of fold and thrust belts.The experiment itself is graded as part of the lab materials.

Analysis: To receive a high mark, You must create a clean, entertaining, informative video that explains the motivation, experimental setup, model results, and analysis. The video quality must be good. The analysis should cover the main observables resulting from the experiment, as well as how these results fit into the classroom wide experiment and a more global understanding of fold and thrust belts.

To receive a passing mark, you must create an informative video that explains the majority of the motivation, experimental setup, model results, and analysis. The analysis should cover the main observables resulting from the experiment.You will receive a failing mark if there is no video, or if the video does not explain the experimental setup, model results, and a brief analysis.

Rubric for Laboratories: Assignment (28%)

Of this score, this grade is assigned according to the following breakdown:

In class exercises (5 total)	22.20%
Lab 1	11.10%
Lab 2	11.10%
Lab 3	11.10%
Lab 4	11.10%
Lab 5	11.10%
Lab 6	11.10%
Lab 7	11.10%

You will complete weekly lab assignments and turn them in. The topics and methods of the assignments will vary: some will involve computer analysis using specialized software, while others will involve the interpretation of paper maps, rock samples, and other forms of geological data.

To receive a high mark, students must complete the assignments with careful attention to detail and using proper technique. Maps should be clean, correct, and attractive; explanations should be clear and based on material learned in class; cross sections should be correct and thoughtful; drawings should be careful and detailed; calculations should be correct and show method as well as result.

In-class exercises will be started in class and completed as homework if necessary. You will be graded according to completeness and correctness - correct use of equations and methods; attention to detail in plotting; correct and complete answers to short answer questions.

In all cases, partial credit will be given when methods are explained and correct, even if the result is incorrect. The emphasis is on the application of techniques and assessment of whether results are plausible, rather than on whether the result is definitively correct.

Although you are encouraged to work together, you must turn in your own materials and be able to justify them; copying materials from another student is considered cheating.

Rubric for Laboratories: Log Book (10%)

On our field trip, you are expected to keep a clear, well-organized field notebook, to be turned in at the end of the trip. To receive a high mark, the field notebook must provide clear and relevant descriptions of field trip sites, including locations, times, weather conditions, personal observations, sketches, personal interpretations. Notes should be detailed and reflect careful and independent observations.

To receive a passing mark, the field notebook must provide relevant descriptions of field trip sites, including some locations, times, weather conditions, personal observations, sketches, personal interpretations. To receive a fail mark, the field notebook must be incomplete, for instance lacking descriptions of several stops, or no sketches.

Rubric for Laboratories: Presentation (10%)

On the field trip, each student will present on a topic chosen in advance. Half of the presentation grade will be based on the 1-page handout prepared in advance, and half will be based on the delivery of the content.

Materials: To receive a high mark, the handout must have appropriate and useful figures, clear text, clear citations, and at least two citations not from the internet. To receive a passing mark, the handout must have figures and text that are relevant and useful.

Presentation: To receive a high mark, you must communicate clearly and loudly, have a clear outline, be engaging, and effectively communicate the main points of your topic. You must also answer students' questions clearly and concisely. To receive a passing mark, you must effectively communicate the main points of your topic.

Rubric for Mid-semester Quiz: Short Answer Questions (40%)

There will be two mid-semester quizzes, one in the middle of the semester and one at the end, each worth 20% of the total grade.These tests will consist of short answer questions: analyzing maps and images, exercises, explaining phenomena, and giving content knowledge.

To score a high mark, you must provide complete, clear answers to the questions on the quiz, including correct calculations and informative drawings where appropriate, and be capable of naming and explaining the geological processes discussed in class and lab.

To receive a passing mark, you must provide mostly complete answers to the questions on the quiz, including usually correct calculations and drawings where appropriate, and usually be capable of naming and explaining the geological processes discussed in class and in lab.

Appendix 2: Intended Affective Outcomes

As a result of this course, it is expected you will develop the following "big picture" attributes:

Competence and independence in the field

A general understanding of how rocks deform in response to stresses

The ability to link large-scale tectonics to small-scale deformation