LECTURE/SESSION SCHEDULE

Wk	Lecture	Practical
1	Metamorphism and it's progressive nature {Ch.21*}	The metamorphic facies
2	Classification of metamorphic rocks {Ch.22*}	Textures of different types of metamorphism
3	Recrystallisation and metamorphic textures {Ch.23.1-3^}	Porphyroblasts and inclusion trails
4	Structures and regional metamorphism {Ch.23.4-6^}	Petrographic shear zone analysis
5	Stable mineral assemblages {Ch.24*}	Mineral chemistry & recalculating cations
6	Metamorphic facies and mafic rocks {Ch.25*}	Ternary chemographics
7	Metamorphic reactions {Ch.26^}	Basin analysis – Pembroke Valley
	Break	
8	Faults and other brittle structures (Session 23^)	Stereonet revision & fault analysis
9	Strain and tectonite concepts [Ch. 2; pp. 51-70*]	Practical strain measurement
10	Fold Mechanics [Ch. 7; pp. 396-413*]	Geometrical analysis using vergence and facing
11	Strain and progressive deformation [Ch. 9; pp. 551-563^]	Valenta Cove and Mycheebye Creek map and outcrop analysis
12	Superposed folds (Session 22^)	Fergusson Creek
13	Applications of strain to shear zones [Ch. 9; pp. 493-551^]	

{Ch.21} = Chapter 21 in the Winter textbook
[Ch.9] = Chapter 9 in the Davis and Reynolds textbook
(Session 22) = Session 22 in the Ramsay and Huber textbook
* Available in the appendix
^ Available on library e-Reserve

IMPORTANT DATES:

Week 3/4 – On campus session and practical examination Saturday 20th August (or Monday 22nd August) 9am – 5pm; E7A 123 (temporary 3rd year petrology lab)
Week 5 – Research assignment 1 due Friday 2nd September
Week 11 – Research assignment 2 due Friday 28th October
Exam: To be advised once the examinations timetable is drawn up

MACQUARIE UNIVERSITY
DEPARTMENT OF EARTH AND PLANETARY SCIENCES
FACULTY OF SCIENCE

GEOS344
Structural and Metamorphic Geology
GEOS882
Advanced Structure and Metamorphism

Unit Outline – Semester 1, 2010 – External

Unit Coordinator: A/Prof. Nathan Daczko
9850-8371
nathan.daczko@mq.edu.au
Room 509, E7A

Credit Points: 4

Contact hours: 1-day on-campus session (and three optional Mondays)

Pre-requisites: GEOS230 or GEOS207 or GEOS900 or GEOS910

Website: http://learn.mq.edu.au (via Blackboard CE6)

INTRODUCTION

The Earth is a dynamic system in which rocks can be physically affected by changing conditions at all stages of the rock cycle: basin formation, folding and thrusting, metamorphism and uplift. These processes have profoundly affected most of the older (Archaean to Palaeozoic) rocks of the Australian craton, but occur also to varying degrees in Mesozoic and Tertiary rocks and at presently active continental margins and plate boundaries. Consequently, an understanding of them is relevant to geological studies of all kinds in rocks of all ages, whether concerned with the history of complex mobile belts, the formation and deformation of mineral and energy deposits, tectonics, or the evolution of sedimentary basins. The processes involved also span the complete range of scales for the Earth, from microscopic to global, and are being actively investigated by many different research groups around the world at the present time.

Structural geology and metamorphic petrology typically form integral components of university degree programmes in Geology. Together with other subjects - especially field mapping, studies of igneous and sedimentary rocks and tectonics - they provide a broad appreciation of the diverse range of geological environments and processes that occur in the Earth. In the Department of Earth & Planetary Sciences, these two topics are covered by GEOS344.

The relationships to other units currently on offer by the Department are detailed as follows. 344 relates to 307 in terms of more advanced study of structures and metamorphic processes with a lesser field focus. It is related to 343 (a) through commonality of some techniques for determining PT condition from phase relations, (b) through metamorphic-plutonic associations and (c) through the role of structure in forming or deforming mineral deposits. The relation to 385 is mainly through tectonics, which is treated on the global scale in that unit as contrasted with more detailed examination of particular belts at local to regional scale in 344.

GEOS344 aims to provide the student with a broad overview of the way rocks respond to changing physical conditions in a selection of the settings mentioned above. Unlike the 200-level units, it is much more concerned with mechanisms and processes. It is also concerned with recognition, description and analysis of common structural and metamorphic effects. Students will thus gain recognition and observation skills and knowledge that will provide them with a foundation for later independent work, whether in industry or as background for more advanced study specialising in the these fields. In addition, generic skills will be gained that can be of practical value in some geoscience professions, notably mine geology and geotechnology.

KEY LEARNING OBJECTIVES

There are five main objectives in this unit:

- To gain an appreciation of the causes and manner of formation of common structures (including faults, folds and cleavage) and metamorphic minerals and textures.
- To gain a working knowledge of time-sequence concepts, especially structural history and metamorphic history.
- To be proficient in the application of some elementary techniques, including stereographic analysis of folds and faults, cross-section construction, total-strain analysis, petrographic description of metamorphic textures, and interpretation of metamorphic conditions from P-T diagrams.
- To understand the elements of structural and metamorphic styles in contrasting tectonic environments.
- To further develop skills in teamwork, independent observations, and written presentation of scientific information.

STUDENT LEARNING EXPERIENCES

Each week students will be required to:
1) Watch one lecture on DVD
2) Read a part of a chapter from a textbook [available from e-Reserve or in this booklet]
3) Complete some practical exercises

Each fortnight [two weeks] each student will be required to:
1) Take a sixty-minute online quiz [These will consist of multiple choice, true-false, matching game, one word answer style questions and be open book - there will be six over the semester. The questions will be drawn from the readings, lectures and practical exercises. These will only be available for two weeks each, i.e. if you miss one – you get zero for that quiz.]

Over the semester each student will be required to:
1) Complete two small research assignments
2) Attend a one-day on-campus session
3) Sit a final exam

Optional:
1) Attend three Monday (full-day) sessions [These are offered in response to the survey of last years class who suggested that more *optional* face-to-face time would improve the unit, especially for students not accustomed to external study]

The specific topics and principal dates are listed in the Schedule at the start of the unit outline.

ASSESSMENT

The assessment consists of several components, listed below. A satisfactory standard is required in all components.

Fortnightly quiz	30% (5% each)
Research assignments	20% (10% each)
Practical and Final examinations	50%

Formal assessment tasks comprise the fortnightly quizzes, two research assignments, and the final examination. Whereas information may be shared when preparing for these tasks, the tasks themselves should be the work of each individual. Referenced statements that indicate the sources (whether from written or electronic material or from other students) are acceptable. Please use the referencing style outlined in the appendix.

The practical examination at the on campus session will test your basis petrographic microscope skills. The final examination will cover all aspects, both theoretical and practical (except practical work on hand samples), that are dealt with in the unit. The questions will include some parts about concepts, processes, the meaning of terms, etc., and other parts that apply the concepts or techniques in the form of problems, much like the written exercises carried out in the practical classes.

ASSESSMENT TASKS

The dates for submission of assessment tasks are listed on the first page of the unit outline.

Extensions for submission of assessment tasks will be given only for illness or misadventure, which must be supported by documentation and a written request. This request should also indicate the extension period required. Assessment tasks submitted late without approval will be penalised 10% of the potential total mark per day late. Students must keep a photocopy of their reports.

Queries, appeals and special consideration
In the first instance, contact the unit convenor if there are any questions about the assessment tasks themselves, or about the comments and grades that you receive for your assignments or reports. You are permitted to appeal against your final grade in any of your units. Before initiating an appeal, discuss your unit grade fully with the unit convenor. More details of the Faculty of Sciences' appeals procedures are available in the Science Centre, ground floor E7A (phone: 9850 6000). The University's special consideration policy can be found at: http://mq.edu.au/policy/docs/special_consideration/policy.pdf

The Dangers of Plagiarism and how to avoid it
The University's policy can be found at: www.mq.edu.au/policy/docs/academic_honesty/policy.pdf
The integrity of learning and scholarship depends on a code of conduct governing good practice and acceptable academic behaviour. One of the most important elements of good practice involves acknowledging carefully the people whose ideas we have used, borrowed, or developed. All students and scholars are bound by these rules because all scholarly work depends in one way or another on the work of others.

Therefore, there is nothing wrong in using the work of others as a basis for your own work, nor is it evidence of inadequacy on your part, provided you do not attempt to pass off someone else's work as your own.

To maintain good academic practice, so that you may be given credit for your own efforts, and so that your own contribution can be properly appreciated and evaluated, you should acknowledge your sources and you should ALWAYS:

1. State clearly in the appropriate form where you found the material on which you have based your work.
2. Acknowledge the people whose concepts, experiments, or results you have extracted, developed, or summarised, even if you put these ideas into your own words.

3. Avoid excessive copying of passages by another author, even where the source is acknowledged. Find another form of words to show that you have thought about the material and understood it, but remember to state clearly where you found the ideas.

If you take and use the work of another person without clearly stating or acknowledging your source, you are falsely claiming that material as your own work and committing an act of PLAGIARISM. This is a very serious violation of good practice and an offence for which you will be penalised.

YOU WILL BE GUILTY OF PLAGIARISM if you do any of the following in an assignment, or in any piece of work which is to be assessed, without clearly acknowledging your source(s) for each quotation or piece of borrowed material:

1. Copy out part(s) of any document or audio-visual material, including computer-based material.
2. Use or extract someone else's concepts or experimental results or conclusions, even if you put them in your own words.
3. Copy out or take ideas from the work of another student, even if you put the borrowed material in your own words.
4. Submit substantially the same final version of any material as a fellow student. On occasions, you may be encouraged to prepare your work with someone else, but the final form of the assignment you hand in must be your own independent endeavour.

Feedback
Feedback on assessment tasks is given in this unit in the following ways:
1) Our primary mode of assessment feedback: the assessment marker will present overall feedback to the class, at either a lecture or in a tutorial, on what aspects of the assignment were done best and where improvement is needed in general.
2) Students are strongly encouraged to seek further feedback (at the time it is given or by making an appointment with the assessment marker) if they are unsure of any aspect of the feedback or if they want further feedback.
3) We provide you with assignment cover pages in the unit of study booklet that, on the reverse side, have a checklist of what is asked in the assignment and a detailed breakdown of the marks awarded for each component. Scoring full marks for a given component indicates that you did exceptionally well. Alternatively, scoring poorly in a component strongly suggests it required further work.
4) In the instance of scoring very poorly overall, you will be provided with written feedback on the assignment indicating where you could improve.

EVALUATION

We are interested in your ideas about how the unit is progressing and how it can be improved. If you have any particular comments (good and bad) or ideas on how to make the unit better please let the unit convenor know. There have been many changes made to previous offerings over the past few years based on student feedback. For example, the assignments are now smaller and their deadlines have been moved to times students indicated they had a lower assignment load. In another example, we introduced the online quizzes in 2008 following feedback from students who requested a more structured guide to their at home study time. Most students find this very useful as it makes them read the background notes and readings. We have also switched the order of practicals 3 and 4 following student advice.

TEXTS AND REFERENCES

Unit of study booklet
This contains material that will be referred to in lectures and the laboratory practical exercises. The booklet is essential for you to have to follow the lectures and laboratory sessions, but you will gain from supplementing the diagrams by your own explanatory notes. The completed worksheets are invaluable as an aid during revision for the examination.

Textbook

There is no set textbook for GEOS344. The chapters set for reading are available in the appendix or via e-Reserve in the library. This booklet contains all the basic information. However, if you would like to purchase a text we recommend the following texts from which the readings are drawn:

1. Winter, J.D., 2001: An Introduction to igneous and metamorphic petrology. Prentice-Hall, 697 pp {QE461 .W735/2001} [This text is also the prescribed text for GEOS314 in first semester]
2. Ramsay, J.G. & Huber, M.I., 1987. The techniques of modern structural geology, Vol. 2: Folds and Fractures. Academic Press, 309-700 pp {QE 601.R2542 1987}
3. Davis, G.H. & Reynolds, S.J., 1996. Structural geology of rocks and regions. 2nd ed. Wiley, 776 pp {QE 601.D3/1996}

Reading List

You may find the following books helpful for reference. They should provide useful supportive material to the lectures, case studies and laboratory exercises, and supplement the Unit of study booklet.

** indicates a book in Special Reserve in the Library; * indicates a book on 3-day loan.

*Bucher, K. & Frey, M., 2002. Petrogenesis of metamorphic rocks. 7th ed. Springer-Verlag, 341 pp {QE475.A2 B84 2002}
**Davis, G.H. & Reynolds, S.J., 1996. Structural geology of rocks and regions. 2nd ed. Wiley, 776 pp {QE 601.D3/1996}
**Dennis, J.G., 1987. Structural geology, an introduction. Brown, 448 pp {QE 601 .D38/1987}
**Marshak, S. & Mitra, G., 1988. Basic methods of structural geology. Prentice-Hall, 446 pp {QE 601.M365/1988}
*Passchier, C.W. & Trouw, R.A.J., 2005. Microtectonics. 2nd ed. Spinger, 366 pp {QE440 .P38 2005}
**Ramsay, J.G. & Huber, M.I., 1987. The techniques of modern structural geology, Vol. 2: Folds and Fractures. Academic Press, 309-700 pp {QE 601.R2542 1987}
*Shelley, D. 1993: Igneous and metamorphic rocks under the microscope: classification, textures, microstructures, and mineral preferred-orientations. Chapman & Hall, 445 pp {QE461 .S4815/1993}
*Spear, F.S. 1993. Metamorphic phase equilibria and pressure-temperature-time paths. Mineralogical Society of America, 799 pp {QE475.A2 .S678/1993}
**Suppe, J., 1985. Principles of structural geology. Prentice-Hall, 537 pp {QE 601.S94/1985}
*Vernon, R.H. 2004: A practical guide to rock microstructure. Cambridge, 594 pp {QE434 .V37}
**Winter, J.D., 2001: An Introduction to igneous and metamorphic petrology. Prentice-Hall, 697 pp {QE461 .W735/2001}
*Yardley, B.W.D., 1989. An introduction to metamorphic petrology. Longman, 248 pp {QE475.A2 .Y37/1989}

Supplementary References for Specific Topics

(multiple references for a given topic may be considered as alternatives)

stereoplotting:	Leyshon, P.R. & Lisle, R.J., 1996. Stereographic projection techniques in structural geology. Butterworth-Heinemann, 104 pp {QE601.3.S83 .L49/1996}
microstructures:	Borradaile, G.J., Bayly, M.B. & Powell, C.McA. (ed's), 1982. Atlas of deformational and metamorphic rock fabrics. Springer-Verlag, 551 pp {QE475.A2 .A87)
strain analysis:	Ramsay, J.G. & Huber, M.I., 1983. The techniques of modern structural geology, Vol. 1: Strain analysis. Academic Press, 307 pp {QE 601 .R254 1983}
tectonics:	McClay, K.R. (ed.), 1992. Thrust Tectonics. Chapman & Hall, 447 pp {QE606 .T57/1992}
tectonics:	Moores, E.M. & Twiss, R.J., 1995. Tectonics. Freeman, 415 pp {QE601 .M65/1995}
tectonics:	Park, R.G., 1988. Geological structures and moving plates. Blackie, 337 pp {QE601 .P345/1988}

Library Loans
The Library at Macquarie will have provided you with information on library loans. The procedures differ for metropolitan and country students. Please familiarise yourself with the procedures appropriate in your case. If you have any enquiries contact the Library on (02) 9850-7500.

Good studying and much success in Structural and Metamorphic Geology

RESEARCH ASSIGNMENTS

Research Assignment 1:

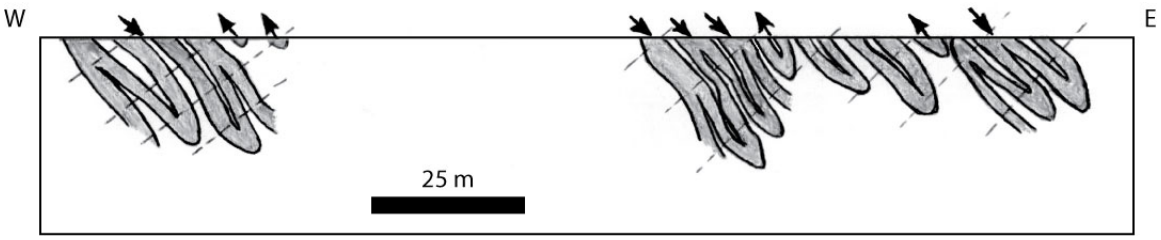
a) [5 marks] Prepare a half-page size P-T graph (P = 0-18 kbar, T = 0-1000°C) showing the general P-T space covered by each of the metamorphic facies: hornfels, zeolite, prehnite-pumpellyite, blueschist, greenschist, amphibolite, granulite, and eclogite. Add to this diagram a dashed line showing a "typical" continental geotherm and the aluminosilicate triple point with lines dividing the fields of andalusite, sillimanite and kyanite stability.
b) [2 marks] Produce a table with 5 columns (titles = Facies, Ultramafic, Mafic, Pelitic, Calcareous) and 9 lines (the titles line and one line for each facies). Fill this table with characteristic minerals for each of the principal rock compositions in each of the metamorphic facies.
c) [1 mark] Why do the different rock types have different characteristic mineral assemblages?
d) [5 marks] Prepare a second P-T graph (same scale as above) showing two P-T paths for the following scenarios: (Rock A) oceanic crust that is subducted to depths of 55 km, when the plate tectonic setting changes and subduction stalls. The crust stays at ~55km for the next 100 Ma (this is long enough for the cold oceanic crust to heat up to the stable geotherm, when there is another sudden change in plate tectonic setting and the rocks are exhumed to the surface in less than 1 Ma (this is not long enough for the rocks to cool and so they will arrive near the surface quite hot and then only cool rapidly when near the surface), and (Rock B) a sedimentary package of interbedded pelitic and psammitic rocks are buried in a deep sedimentary basin to depths of 15 km over 5 Ma. Over the next 150 Ma they are heated at a "typical" continental geotherm, after which time the rocks are slowly and erosionally exhumed to the surface. Note: 10 kbar = 1 GPa and a general rule of thumb is 10 km ≈ 3 kbar or 1 kbar ≈ 3 km.
e) [5 marks] When a geologist stumbles across rocks A and B in the field, what peak mineral assemblages do you think they will observe in hand sample and/or thin section?
f) [2 marks] What are (i) symplectites, and (ii) corona textures?
g) [10 marks] Conduct a literature research on the topic of low-P, high-T metamorphic belts known as "regional aureoles". Cite examples of such belts and explain the range of models for how they form in less than one page of text (excluding references and figures).

Research Assignment 2:

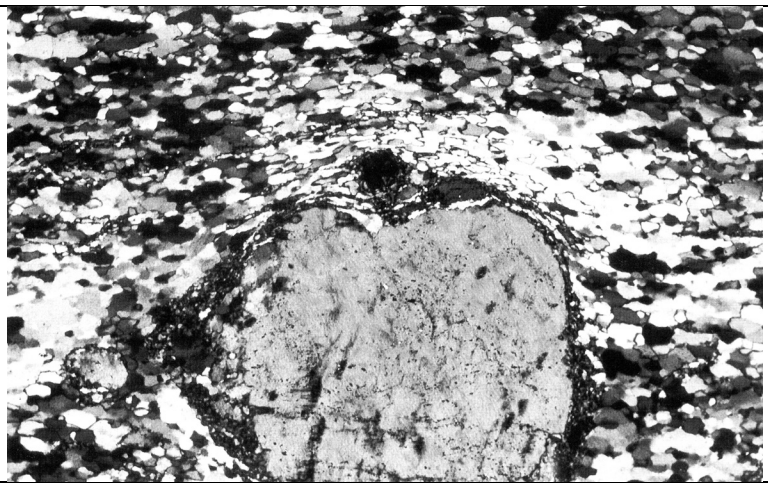
a) [4 marks] Create a classification flow chart for metamorphic rocks (1 A4 page). Include in the flow chart: slate, phyllite, schist, gneiss, hornfels, marble, quartzite, microbreccia, cataclasite, mylonite, and pseudotachylite.
b) [2 marks] What are (i) dynamic recrystallisation, and (ii) annealing?
c) [3 marks] Discuss plastic intracrystalline deformation (using text and sketches), including (i) crystal lattice defects, (ii) dislocation glide, and (iii) dislocation creep.
d) [4 marks] Discuss recrystallisation (using text and sketches), including (i) grain boundary migration, (ii) sub-grain rotation, (iii) solid-state diffusion creep, and (iv) grain boundary area reduction.
e) [1 mark] In regional metamorphic terranes, what is the difference between S-tectonites, L-tectonites, and L-S-tectonites? Use sketches in your answer.

[Questions for research assignment 2 continue on the next page.]

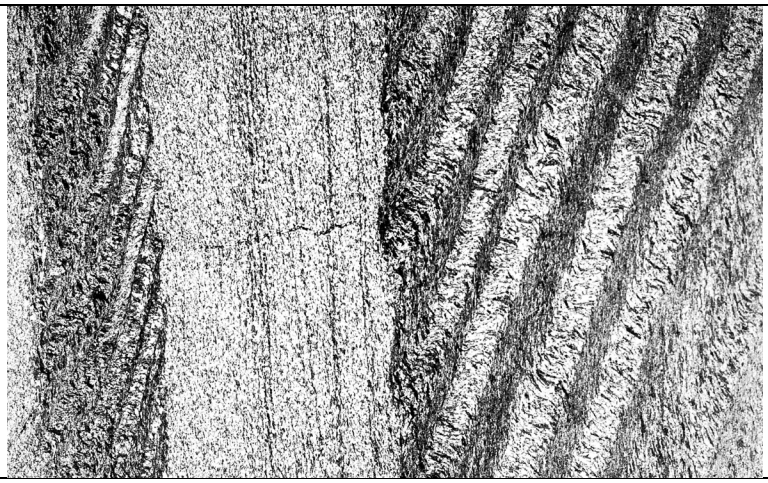
f) [8 marks] The figure below shows an incomplete cross section of folded quartzites and schists. Tight F_2 folds that can be traced in outcrop are shown, the folded surface is bedding (S_0). Facing directions (arrows) are shown where they are available. Late (F_3) open folds and their axial planes (dashed lines) are also shown. Finish the cross section using the style of folding shown and the facing directions. Connect all layers with solid lines below the surface and dashed lines above the surface.



g) [8 marks] Answer the questions for the following photomicrographs:



(i) Describe and explain the fabric.



(ii) Name the foliations and describe their origin.