ESS 431: BASIN ANALYSIS
(The former GLG430 and ES332, but still with the same exciting flavours)

Instructor:

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Introduction

The objective of this course is to discuss the evolution of sedimentary basins in a global context, starting off with a series of lectures explaining why sedimentary basins are important: they are the main repository of fossil fuels (Climate change might have implications for fossil fuels, but we are still going to need them for a long time to come).

Crustal and mantle processes that lead to the development of sedimentary basins are described, and the processes that control subsidence, sea-level change and sediment supply are discussed. We review the principles of sequence stratigraphy, focusing mainly on siliciclastic deposits, examine the controversy surrounding the "global cycle chart" and evaluate the nature of the evidence for regional and global stratigraphic cycles. This material is then synthesized in a discussion of the structural and stratigraphic styles of sedimentary basins in a plate-tectonic context.

Recommended textbooks

"*Sediments and Basins*" by A. D. Miall, a Custom-Courseware text prepared for University of Toronto by McGraw-Hill Ryerson, and available from the bookstore.
ESS 431 is covered in Chapters 9-13 of this book.

Other useful books

"*Stratigraphy: A Modern Synthesis*", Springer-Verlag, New York, 454 p.

"Principles of sedimentary basin analysis", Third edition, by A. D. Miall, Springer-Verlag Inc., New York, 2000.
This book is used as a recommended text for all sedimentology-stratigraphy courses taught by Prof. Miall. The third edition makes an ideal advanced textbook for the course. ESS 431 is dealt with in Chapters 6 to 9.

"The evolving continents", second edition, by B. F. Windley, John Wiley and Sons, Chichester, 399 p., 1984.
"Plate tectonics and crustal evolution", third edition, by K. C. Condie, Pergamon Press, Oxford, 476 p., 1989.
These two books use a historical approach to explore the history of the earth. Of the two, the book by Windley is probably the more useful for this course, because it deals in more detail with the structural and stratigraphic history of many of the world's major orogenic belts.

"*Facies models: Response to sea-level change*", edited by N. P. James and R. W. Dalrymple, 4th edition, 2010

Description of modern concepts of facies analysis as applied to the various major depositional environments. Discusses the response of depositional systems to sea-level change, and therefore provides an important basis for the study of sequence stratigraphy. This has become the standard introductory text on the subject, and is used for teaching purposes worldwide. It is currently in its fourth, completely revised edition

"The geology of stratigraphic sequences", second edition, by A. D. Miall, Springer-Verlag, New York, 522 p., 2010
"Sequence stratigraphy", by D. Emery and K. J. Myers, Blackwell Science, 297 p., 1996
These two books focus on the sequence stratigraphic revolution. That by Miall emphasizes the variety of sequence generating mechanisms and difficulties with the global cycle chart. It discusses all the current controversies. The book by Emery and Myers describes in detail systems tracts and depositional models. It does not deal with the controversies in sequence interpretation.

Principles of sequence stratigraphy: by O. Catuneanu, Elsevier, Amsterdam, 375 p., 2006
This has become the standard textbook on sequence definitions and models. Very well illustrated (Catuneanu was my former Ph.D. student, and is now a Professor at Uxniversity of Alberta)

"*Sedimentary environments and facies*", third edition, edited by H. G. Reading, Blackwell Scientific Publications, Oxford, 1996 (abbreviation "R").
This is a standard advanced textbook on the subject. Facies analysis methods and facies models are covered in much the same way as in Walker and James, at a much more advanced level, but by now a little out of date in a few areas. Not a useful book for reading up on sequence stratigraphy.

"*Phanerozoic sea-level changes*" by A. Hallam, Columbia University Press, 1992.
A readable book on the Phanerozoic history of major sea-level changes, with discussions of how to measure such changes, and what causes them.

"*The new catastrophism*" by D. Ager, Cambridge University Press, 1993.
A readable, non-technical book summarizing modern thinking on dramatic events in earth history, such as the asteroid impact theory for terminal Cretaceous extinctions.

"Tectonics of sedimentary basins", edited by C. J. Busby and R. V. Ingersoll, Blackwell Science, Oxford, 579 p, 1995.
Treatment at an advanced, graduate level, of the material covered in Chapter 9 in Miall's "*Principles*". Numerous references and illustrations.

"Stratigraphy: A modern synthesis" A new book designed to replace my "*Principles* …" in the area of stratigraphy. Currently "in press" with Springer Verlag, and should appear early in 2016.

Course outline

It is essential that the student be familiar with major facies analysis principles, including the flow regime concept, and the use of Walther's law in vertical profile analysis—material covered in GLG 360/ESS 331. It is suggested that students remind themselves about this material by reading Chapters 6-8 in Miall's "*Sediments and Basins*"

1. Why we spend time learning about sedimentary basins: Non-renewable Energy
   —The “petroleum system”
   —Source rocks, reservoirs, traps
   —Production
   —Environmental issues
   —Distribution of petroleum in Canada and the world
   —Other (“non-conventional”) oil and gas: shale gas, tight oil.

2. Basin subsidence and fill models
   Readings: Miall, “Sediments and Basins”, Chapter11
   —why does the crust subside to form basins?
   —extensional basin models (Atlantic-margin type basins)
   —basins produced by supracrustal loading (foreland basins)
   —components of a basin model, backstripping techniques
   —the numerical modelling approach to understanding the mechanics of sedimentary basins

3. Sequence stratigraphy
   Readings: Miall, “Sediments and Basins, Chapter 9; Miall “Geology of Stratigraphic Sequences” book, Part I
   —the history of the sequence concept (Barrell, Chamberlin, Grabau, Sloss, Frazier)
   —the contribution of seismic stratigraphy, Vail curves
   —later Exxon contributions, the sequence models of Vail,
   —modern sequence models (Posamentier et al., Hunt and Tucker, Emery and Myers, etc.)
   —systems tracts and sequence models for clastic, carbonate and evaporite environments
   —sequence models for extensional continental margins and foreland basins

4. Regional and global stratigraphic cycles
   Readings: Miall, “Sediments and Basins, Chapter 12; Miall, “Sequences”, Part I
   —cycles with periodicities of tens of millions of years (Sloss cycles) and their causes
   —eustatic changes in sea level caused by volume changes in spreading centres
   —dynamic topography
   —cycles with periodicities of less than one million years. The classic cyclothems.
   —Milankovitch forcing mechanisms. Orbital forcing and oxygen-isotope chronology
   —Tectonic mechanisms of sequence generation. Intraplate stress
   —Distinguishing tectonic from Milankovitch mechanisms

5. Regional versus global sea-level change: a controversy in methodology
   Readings: Miall, “Sediments and Basins”, p. 278-283; Geoscience Canada, v. 21, p. 1-26 (1994), or Miall, “Sequences”, Part IV
   —the Exxon global cycle chart. Why did bad science become so popular?
   —problems with regional and global correlation
   —A discussion of methodology: inductive and deductive science, paradigm creation.

6. A history of COCORP and Lithoprobe
   —The development of deep crustal seismic reflection and its application to structural problems in Canada and the US

7. Sedimentation and plate tectonics (the structural and stratigraphic styles of basins in diverse plate environments)
Readings: Miall, "Sediments and Basins", Chapter 13; See also Busby and Ingersoll.
—Tectonic classification of sedimentary basins
—rift basins
—basins developed on divergent plate margins
—basins developed on convergent plate margins
—transform margins and strike-slip fault basins
—basins associated with suture zones
—basin analysis of accretionary terranes

Exercises
There will be four or five exercises assigned in the first half of term, interpreting subsurface data.

Basin Project exercise
Students will be required to form themselves into pairs, and will be required to choose a basin project to work on for the first part of the term. They will then be assigned part of a class period in the second half of the term to present the project to the class. The project will consist of assembling a synthesis of the regional geological history of one of the world's major sedimentary basins. The students will be expected to put together a computer presentation (Power Point or equivalent) dealing with the basin, and to give an oral presentation. A schedule for poster presentations will be established early in the term.

Term paper
Students will be required to write a term paper on a topic not connected with that covered in their basin project. A list of term paper topics will be circulated separately. Term papers will be due in the last class (April 4th). Late submissions will be subjected to a penalty unless there are valid family or medical reasons for late submission. A doctor's note may be required.

In-Class examination
A two-hour examination will take place in class on March 7th. This will cover the material presented in the first half of the term. No aids will be allowed.

Course evaluation scheme

Laboratory exercises (first half of term)	25% of term mark
Basin presentation (timetable to be set)	15%
In-class final examination (Tuesday 7th March)	35%
Term paper (due Tuesday 4th April)	25%

Given the focus of the course as a co-operative learning process, intended to provide support for each group's members, students are expected to ***attend class regularly***, read extensively, and participate in class discussion. ***To ensure a student's presence and participation in class discussion, up to and including the last class in April, attendance will be taken each week. Absences without cause will be penalized up to 5% of the student's final grade.***

All requirements for this course will be met within the term period (January 10th to April 4th). There will not be a registrar-scheduled final examination. This means that after April 4th students can forget about this course! No further work will be required!