



Earth Sciences 3372A (0.5 FCE)

Fall 2019

Introduction to Petroleum Systems

Calendar Description: The study of the fundamental geological components of petroleum systems responsible for oil and natural gas accumulations in sedimentary basins. The fate of organic matter is traced along a path from source rocks, maturation, migration, to reservoir, trap and seal. Labs incorporate use of industry software. [2 lecture hours, 3 laboratory hours, 0.5 course]

Lectures (beginning Thursday September 5)

Tuesday / Thursday, 11:30 AM – 12:30 PM
Physics & Astronomy Building, room 117

Labs (beginning Monday September 9)

Monday, 2:30 PM – 5:30 PM
Biological & Geological Sciences Building, room 0184

Dr. Burns A. Cheadle

Associate Professor, Department of Earth Sciences
Email: bcheadle@uwo.ca
Office: BGS 1078 / NCB 223
Tel: 519-661-2111 ext.89009
Hours: Fridays, 10:30 – 11:30, or by appointment

Prerequisites: Earth Sciences 2260 A/B

Anti-requisite: (none)

Statement on Requisites: Unless you have either the requisites for this course or written special permission from your Dean to enroll in it, you may be removed from this course and it will be deleted from your record. This decision may not be appealed. You will receive no adjustment to your fees in the event that you are dropped from a course for failing to have the necessary prerequisites.

Description: This course introduces students to the major components of *petroleum systems* and shows how those components interact to create petroleum *plays* and *prospects*. Different plate tectonic settings provide the context for lectures describing how sedimentary basin evolution influences the physical and geochemical characteristics of source, reservoir and seal rocks. Similarly, plate tectonics determine the burial and deformational processes governing the maturation and migration of hydrocarbons and the formation of structural traps. All of these products and processes are synthesized into a coherent geological history that describes the fate of organic matter as it progresses from living

ecosystems to preservation in the upper regions of the Earth's crust.

Progression: Weekly labs reinforce the lecture concepts and show how they are applied in the process of constructing a petroleum prospect map. The lab section uses a project-based learning technique, teaching a progression of analytical and critical evaluation methods including geophysical well log interpretation, petrophysical calculations, and cross-section and map construction. The labs will incorporate the use of geoSCOUT®, a standard industry software package, as well as Excel® and Surfer® to explore and describe the basic characteristics of a petroleum pool.

Transferrable professional competencies such as teamwork, communication, and project management are emphasized throughout the course. Students will be evaluated on a combination of lecture and lab material via short lab assignments, a mid-term essay, and a final exam based on lecture and lab material.

Learning Outcomes (in context of Western Degree Outcomes):

Upon completion of this course successful students will be able to:

- Knowledge
 - Identify and define the major components of petroleum systems.
 - Illustrate and label depositional models for petroleum source rock and reservoir rock facies
 - Classify and compare petroleum trap types in the context of different tectonic settings
 - Interpret geophysical well log data and calculate hydrocarbon pore volume.
 - Critically evaluate petroleum well data and synthesize it into a prospect map
 - Speculate on the roles of plate tectonics and related basin-forming processes in the development of petroleum systems and plays.
- Literacies and Interdisciplinarity
 - Use oilfield technical language to identify, evaluate and integrate various data types
- Communication
 - Use appropriate language and reasoning to present ideas clearly to a variety of audiences
- Resilience and Life-Long Learning
 - Express how personal values and beliefs influence perception of the issues surrounding petroleum exploration and development
- Global and Community Engagement
 - Describe the interconnectedness of technical, economic, social and environmental considerations of petroleum development
- Critical Inquiry and Creative Thinking
 - Assess the reliability of different information sources based on critical evaluation of underlying assumptions, perspectives and quality of evidence
 - Adapt problem-solving strategies according to judgments about data reliability
- Professionalism and Ethical Conduct
 - Work effectively with diverse team members to contribute to a shared objective
 - Explain the ethical responsibilities of a professional geoscientist involved in petroleum development

Lecture Resources Website: <https://owl.uwo.ca> (log in with UWO username and password)

Note: PowerPoint presentations for each lecture will be posted no later than the evening before

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the lecture, and will remain on the website for the rest of the term. Note, however, that **some material in the presentations will be deliberately left out**, requiring you to fill in important terms and other information critical to the topic. You will therefore be required to come to the lectures. It follows that the PowerPoint presentations posted on OWL are not to be used as a substitute for coming to class (you have been warned). It is up to you to download the presentations when they are available and to obtain information from your classmates if you miss a class.

Course Syllabus

(Note: This is an outline of topics that will be covered, but we will adjust the emphasis on certain topics if the class has specific interests or requires more in-depth explanation. The first 15 lectures constitute the core syllabus, and one or more of lectures 16 through 18 will be offered if time permits. Consequently, lecture numbers may not necessarily correspond to a standard 50-minute lecture.)

Lecture Topics

Foundations

1. Constant Craving

- How does petroleum fit into the larger picture of global energy consumption and production?
- academic and applied petroleum geoscience
- course outline and objectives

2. Get it Together

- fundamental concepts of petroleum systems
- components of a petroleum system

3. Play On

- uncertainty and risk
- play maps and classification
- prospects and plays

Basin Setting

4. A Whole Lotta Shaking Going On

- Basins and tectonic settings
- extensional basins
- flexural basins
- translational basins

Source & Migration

5. Black Rain

- production of sedimentary organic matter
- preservation of organic matter
- organic matter types & kerogen

6. The Deep Dark

- source rock characteristics
- mudrock sedimentology
- depositional settings of source rocks

7. Cooking in the Kitchen

- kerogen pyrolysis
- source rock quality
- primary migration
- 8. **Movin' On**
- secondary migration
- carrier bed characteristics
- migration efficiency

Reservoir

- 9. **Save Me**
- fundamental reservoir attributes
- storage capacity and porosity
- flow capacity and permeability
- 10. **Riders on the Storm**
- source to sink – the clastic depositional continuum
- fundamentals of clastic sequence stratigraphy
- 11. **Day at the Beach**
- sedimentology of wave-dominated shorelines
- architecture of clastic shoreface reservoirs
- exploration and development of shoreface plays
- 12. **Living on the Edge**
- the carbonate factory
- carbonate platforms and ramps
- fundamentals of carbonate sequence stratigraphy
- exploration and development of reef plays

Traps: Closure & Seal

- 13. **Bump and Grind**
- structural closures
- fault-dependent closures
- independent closures
- 14. **The Dark End of the Street**
- stratigraphic traps
- diagenetic traps
- 15. **Signed, Sealed, Delivered**
- seal properties
- capillary pressure
- hydrocarbon columns

Canada's Oil and Gas Industry

- 16. **Heavy Oil and Oil Sands**
- the Mannville oil sands play
- bitumen mining
- in situ extraction
- 17. **Tight Oil and Shale Gas**

- self-sourcing oil and gas plays
- low permeability plays
- hydraulic fracture treatments

18. Pipeline

- challenges facing the Canadian petroleum industry
- commodity cycles
- meeting public expectations

Lab Topics

geoSCOUT Basics

1. Orientation

- oil and gas drilling operations
- sources of petroleum geology data
- survey systems and well identifiers

2. Querying Well data in geoSCOUT

- oil and gas well data categories
- simple queries
- complex queries

3. Introduction to Well Logs

- logging operations
- routine log measurements
- combining log responses

4. “Quicklook” Log Interpretation

- lithology responses
- porosity responses
- fluid responses
- combining log characteristics

5. “Quantitative Petrophysics”

- clay volume estimation
- effective porosity estimation
- water saturation estimation
- HCPV and net pay

6. Well Log Stratigraphy

- cross-section construction
- stratigraphic correlation
- loop-tied gridding

7. Structural Mapping*

- data management
- posting structural data
- contouring structural data
- isopach mapping technique

8. Facies Mapping

- log patterns for facies interpretation
- facies in stratigraphic context
- paleogeographic reconstruction

9. Prospect Mapping*

- prospect map components
- ordered map layers
- sweet spot identification

10. Reserves and Economics

- calculating Original Oil and Gas in Place
- building a production forecast
- calculating Net Present Value

- indicates graded lab assignment

Course Materials

The course does not have a required textbook, but the following resources are suggested for those learners who prefer to supplement lecture material with reference books.

Recommended Text: Bjørlykke, K., 2015. ***Petroleum Geoscience: From Sedimentary Environments to Rock Physics, 2nd edition***. Springer. 662p. (this textbook is available through the Western Library system as a Springer e-book)

Optional Texts: James, N.P. and Dalrymple, R.W. (editors), 2010. ***Facies Models 4***. GEOtext 6, Geological Association of Canada. 586 p. (*this is the required textbook for ES 4460 A/B, and an essential reference for aspiring petroleum geologists*)

Allen, P.A. and Allen, J.R., 2013. ***Basin Analysis: Principles and Applications***. 3rd edition. Blackwell. 619 p. (*Part 4 is particularly relevant to petroleum geology*)

Methods of Evaluation

OWL quizzes (20% of total): (*5 short multiple-choice quizzes; one hour time limit; due Monday midnight*)

- *combination of lecture and lab material*

Graded Labs (15% of total): (*3 graded lab assignments due by the beginning of the following lab session*)

- *assignments involve application of cumulative lab learning*

Mid-Term Exam (20% of total): (*Thursday October 24 during scheduled lecture period; 45 minutes*)

- *mixed format exam based on cumulative lecture material*

Final Exam (40% of total): (*during the scheduled exam period*)

- *mixed format exam based on cumulative lecture and lab material*

Participation (5% of total): (*to be assigned following final lecture period*)

- *participation rubric will be provided*

Due dates for assignments are firm – late submissions will not be accepted. See note (4) under "University Policies" for exceptions due to illness or special circumstances where the missed course component is worth 10% or more of the final grade. Note that the instructor will grant accommodation for work worth less than 10% of the final grade without the requirement for documentation, medical or otherwise.

Use of electronic calculators is permitted during examinations, but all other electronic devices (phones, tablets, laptops) must be turned off for the duration of the examination period

Sessional Dates (ES 3372A specific dates in bold)

September 5	Fall/Winter Term classes begin
September 5	ES3372A lectures begin (8:30 – 9:30 BGS 0153)
September 9	ES3372A labs begin (10:30 – 1:30 BGS 0184)
September 13	Last day of registration
October 14	Thanksgiving Holiday (NO LAB SESSION)
November 4 -10	Fall Reading Week
November 12	Last day to drop a first-term half course or a first-term full course (2019-20 Fall/Winter Term) without academic penalty.
December 2	ES3372A final lab session
December 5	ES3372A final lecture session (exam review)
December 5	Fall/Winter Term classes end
December 6-7	Study Days
December 8-19	Mid-year examination period

The Exceptional Contributor: “The Class Was Better Because You Were Here.”

As part of the learning process I expect all students to participate actively in class. Here are some guidelines to keep in mind when in class:

- You provide clear, concise, and correct explanations that help others gain a better understanding of concepts.
- You make outstanding, original, and informative comments.
- You make highly attentive and constructive comments on other people's statements.
- You ask questions that are penetrating or help clarify.
- You raise your hand strategically (understanding that there are other students in the class).
- You actively encourage others to express their ideas.
- You display body language that communicates interest in what others are saying.
- You arrive to class on time and are not absent without reason.

University Policies:

1) Scholastic offences are taken seriously and students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence, at the following Web site:

http://www.uwo.ca/univsec/pdf/academic_policies/appeals/scholastic_discipline_undergrad.pdf

2) Unless you have either the requisites for this course or written special permission from your Dean to enroll in it, you may be removed from this course and it will be deleted from your record. This decision may not be appealed. You will receive no adjustment to your fees in the event that you are dropped from a course for failing to have the necessary prerequisites.

3) All required papers may be subject to submission for textual similarity review to the commercial plagiarism detection software under license to the University for the detection of plagiarism. All papers submitted for such checking will be included as source documents in the reference database for the purpose of detecting plagiarism of papers subsequently submitted to the system. Use of the service is subject to the licensing agreement, currently between The University of Western Ontario and Turnitin.com (<http://www.turnitin.com>).

4) If you are unable to meet a course requirement due to illness or other serious circumstances, you must seek approval for the absence as soon as possible. Approval can be granted either through a self-reporting of absence or via the Dean's Office/Academic Counselling unit of your Home Faculty. If you are a Science student, the Academic Counselling Office of the Faculty of Science is located in NCB 280, and can be contacted at scibmsac@uwo.ca.

For further information, please consult the university's policy on academic consideration for student absences:

https://www.uwo.ca/univsec/pdf/academic_policies/appeals/Academic_Consideration_for_absences.pdf

If a student has received academic accommodation, missed components excused (so that the course is reweighted). The instructor will grant accommodation for work worth less than 10% or less.

If you miss the Final Exam, please contact your faculty's Academic Counselling Office as soon as you are able to do so. They will assess your eligibility to write the Special Exam (the name given by the university to a makeup Final Exam). You may also be eligible to write the Special Exam if you are in a "Multiple Exam Situation" (see http://www.registrar.uwo.ca/examinations/exam_schedule.html).

5) Students who are in emotional/mental distress should refer to Mental Health@Western <http://www.uwo.ca/uwocom/mentalhealth/> for a complete list of options about how to obtain help.

6) For the policy on Accommodation for Students with Disabilities, refer to: http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_disabilities.pdf.

7) For the policy on Accommodation for Religious Holidays, refer to: http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_religious.pdf

Registrarial Services: <http://www.registrar.uwo.ca>

Services provided by University Students' Council: <http://westernusc.ca/services/>

Accessibility Statement:

Please contact the course instructor if you require material in an alternate format or if you require any other arrangements to make this course more accessible to you. You may also wish to contact Student Accessibility Services (SAS) at 661-2147 if you have any questions regarding accommodations.