Introduction to Geological Oceanography  
(EASC 2919 and OCSC 2200, Winter 2018)

Lectures:  Monday–Wednesday–Friday; 09:00–09:50 am, ER 3005  
Instructor:  Ali E. Aksu, ER6014, aaksu@mun.ca

Calendar Description
The formation and evolution of oceans are discussed, including plate tectonics, mid-ocean ridges (birth place of oceans), subduction zones (where oceans are consumed), sedimentary environments such as estuaries, deltas, beaches and barrier islands, continental shelves, slopes and deep abyssal plains and special topics, including anoxic events, evolution of tides, atmosphere-ocean interactions, formation of banded iron formations, snowball Earth, black and white smokers, and how Earth modulates its climate through atmosphere, hydrosphere, biosphere and lithosphere interactions.

PR: EASC1000

Course notes
User:  es2919_w18  
Password:  Aptivent  
URL:  https://www.esd.mun.ca/courses/es2919_w18/

Evaluation:

<table>
<thead>
<tr>
<th></th>
<th>%</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Term Test 1</td>
<td>20%</td>
<td>January 31, 2018</td>
</tr>
<tr>
<td>Term Test 2</td>
<td>20%</td>
<td>February 28, 2018</td>
</tr>
<tr>
<td>Term Test 3</td>
<td>20%</td>
<td>March 19, 2018</td>
</tr>
<tr>
<td>Final examination</td>
<td>40%</td>
<td>to be announced by MUN</td>
</tr>
</tbody>
</table>

Information from the University Calendar pertaining to course syllabi

(1) Accommodation of Students with Disabilities: Memorial University of Newfoundland is committed to ensuring an environment of understanding and respect for the dignity and worth of each student and also to supporting inclusive education based on the principles of equity, accessibility and collaboration.  (FYI - this is from: http://www.mun.ca/policy/site/policy.php?id=239)

(2) Academic Integrity: Within the University community there is a collective responsibility to maintain a high level of scholarly integrity. A student is expected to adhere to those principles which constitute proper academic conduct. Academic misconduct cannot be condoned or even appear to be condoned. A student has the responsibility to know which actions, as described under Academic Offences, could be construed as dishonest or improper. A student is reminded that for further guidance on proper scholarly behaviour he/she should seek advice from his/her instructors and faculty advisors.  (FYI – this is from: http://www.mun.ca/regoff/calendar/sectionNo=REGS-0748)
Course structure

I am hoping to finish each lecture presentation within the first 30-35 minutes of the class time, so that we have 15-20 minutes left for in-class discussion of the salient points of lecture.

Course Outline

Week 1
Jan 5 \hspace{2em} Lecture 1 \hspace{2em} Introduction to Geological Oceanography

Lecture Outline
- Introduction of the course
- Definitions of Marine Geology, Geological Oceanography and Paleoceanography
- Diagenesis

Learning Objectives
- to understand the post-depositional changes that occur in sediments/rocks

Week 2
Jan 8 \hspace{2em} Lecture 2 \hspace{2em} Water in the Solar System

Lecture Outline
- Solar Nebula Theory
- Water in the Inner Solar System
- Water in the Outer Solar System

Learning Objectives
- to learn and understand the evidences that water is not a special molecule unique to Earth and that water is ubiquitous in the Solar System

Jan 10 \hspace{2em} Lecture 3 \hspace{2em} Origin and Evolution of the Oceans

Lecture Outline
- Evolution of Earth
  - Homogeneous vs heterogeneous accretion
  - Geological time – Hadean Eon
  - Hypotheses on the origin of water on Earth
  - Terrestrial versus extra-terrestrial origin
- Conclusions

Learning Objectives
- to learn the evidence and understand the arguments made for the origin of water on Earth

Jan 12 \hspace{2em} Lecture 4 \hspace{2em} Early Evolution of Earth and Climate

Lecture Outline
- Introduction to geological time – pre-Cambrian
- Evolution of the crust and early plate tectonic processes
- A time perspective
- Atmosphere–ocean–lithosphere–biosphere interactions
- Climate 1^{st}, 2^{nd}, 3^{rd} and 4^{th} order climate controls and the role of oceans

Learning Objectives
- to learn the earliest evolution of the Earth and understand the role that oceans played in the
development of extreme climate variations in the history of our planet

**Week 3**
Jan 15  **Lecture 5  Ocean-Atmosphere-Lithosphere-Biosphere Interactions**

*Lecture Outline*
- Evidences for dramatic climate fluctuations
  - Paleomagnetic evidence
  - Sedimentological evidence
  - Stable isotopic evidence (next lecture)

*Learning Objectives*
- to learn the evidences for the dramatic ocean-atmosphere-lithosphere interactions in early Earth leading to radical climate fluctuations

Jan 17  **Lecture 6  Neoproterozoic Glaciations**

*Lecture Outline*
- Evidences for dramatic climate fluctuations
  - Stable isotopic evidence (continued)
- Snowball Earth Hypothesis
  (a) Lower solar radiation
  (b) Breakup of the tropically-located Rodinia
  (c) Increased weathering rates
  (d) Lower greenhouse gases CO₂ and CH₄
  (e) Runaway albedo feedback loop
- High Obliquity Hypothesis
- Zipper Rift Hypothesis

*Learning Objectives*
- to understand the potential triggers associated with the various hypotheses for the dramatic climate fluctuations observed in early Earth, and to evaluate whether or not they conform with the geological and geochemical data.

Jan 19  **Lecture 7  Banded Iron Formations – I**

*Lecture Outline*
- Banded Iron Formations – definition
- The Archean and Proterozoic Oceans
  - Ocean chemistry - REE evidence
  - Ocean chemistry - isotopic evidence
- Early Life on Earth
- The Nickel Famine Hypothesis
- The Great Oxidation Event
- Shallow Ocean: Paleoproterozoic Banded Iron Formations
- Deep Ocean: The Proterozoic Sulphidic Ocean Hypothesis

*Learning Objectives*
- to learn the dramatic evolution of our planet and the important role that the oceans played in this evolution

**Week 4**
Jan 22  Lecture 8  Banded Iron Formations – II

*Lecture Outline*
Banded Iron Formations – definition
The Archean and Proterozoic Oceans
  Ocean chemistry - REE evidence
  Ocean chemistry - isotopic evidence
Early Life on Earth
The Nickel Famine Hypothesis
The Great Oxidation Event
Shallow Ocean: Paleoproterozoic Banded Iron Formations
Deep Ocean: The Proterozoic Sulphidic Ocean Hypothesis

*Learning Objectives*
to learn the dramatic evolution of our planet and the important role that the oceans played in this evolution

Jan 24  Lecture 9  Banded Iron Formations – III

*Lecture Outline*
Banded Iron Formations – definition
The Archean and Proterozoic Oceans
  Ocean chemistry - REE evidence
  Ocean chemistry - isotopic evidence
Early Life on Earth
The Nickel Famine Hypothesis
The Great Oxidation Event
Shallow Ocean: Paleoproterozoic Banded Iron Formations
Deep Ocean: The Proterozoic Sulphidic Ocean Hypothesis

*Learning Objectives*
to learn the dramatic evolution of our planet and the important role that the oceans played in this evolution

Jan 26  Lecture 10  Anoxia and Euxinia in Geological Times

*Lecture Outline*
Anoxia and anoxic event – definition
Euxinia and euxinic events – definition
The Archean and Proterozoic Oceans
  Ocean chemistry – anoxia
Long-duration anoxic events in Earth’s history – black shales
Short-duration anoxic events in Earth’s history – sapropels

*Learning Objectives*
to learn about the oxygenation of the oceans and periodic developments of long-term and short-term bottom water anoxia and occasional euxinia which lead to the development of organic-rich shales.

Week 5
Jan 29  Lecture 11  Anoxia and Euxinia in Geological Times

*Lecture Outline*
Anoxia and anoxic event – definition
Euxinia and euxinic events – definition
The Archean and Proterozoic Oceans
Ocean chemistry – anoxia
Long-duration anoxic events in Earth’s history – black shales
Short-duration anoxic events in Earth’s history – sapropels

Learning Objectives

to learn about the oxygenation of the oceans and periodic developments of long-term and short-term bottom water anoxia and occasional euxinia which lead to the development of organic-rich shales.

Jan 31           Test 1            Term test – lectures 1 – 11 (20% of final grade)

Feb 2            Lecture 12        Tides and Tidal Rhytmites – I
Lecture Outline
Introduction to tides
Tidal interaction with sediments
Tidal sediments and structures characteristic of tides
Tidal bundle and tidal bundle sequence
Calculation of the length of a Devonian day in hours
Calculation of the length of a Devonian year in days

Learning Objectives

to learn the evidence and methods used in the idea that the friction between the tides and the Earth slows down the rotation of the Earth and increases the Earth-Moon distance

Week 6

Feb 5            Lecture 13        Tides and Tidal Rhytmites – II
Lecture Outline
Introduction to tides
Tidal interaction with sediments
Tidal sediments and structures characteristic of tides
Tidal bundle and tidal bundle sequence
Calculation of the length of a Devonian day in hours
Calculation of the length of a Devonian year in days

Learning Objectives

to learn the evidence and methods used in the idea that the friction between the tides and the Earth slows down the rotation of the Earth and increases the Earth-Moon distance

Feb 7            Lecture 14        Development of the Plate Tectonics Theory
Lecture Outline
Review of early ideas about major Earth processes
Review early evidences leading to Plate Tectonic Theory
Connecting the dots – the data were unequivocal

Learning Objectives

to learn the evidences that allowed the development of an eloquent theory regarding the most fundamental of the Earth processes
Feb 9      Lecture 15     Driving Forces of the Plates

Lecture Outline
   Review isostasy and plate motion
   Review mantle convection and hotspots
   Review plate forces

Learning Objectives
   to learn the fundamental Earth processes that drive plates to move, and to understand the perpetual opening and closing of oceans and formation and splitting of supercontinents

Week 7
Feb 12     Lecture 16     Earth’s Interior, Wilson Cycles

Lecture Outline
   GPS measurement is plate motion
   Wilson Cycles – “Harry Hibbs’ accordion”

Learning Objectives
   to achieve an understanding (at moderate level) of the fundamental processes that takes place in divergent, convergent and transform plate boundaries, and the structures and associations that develop in each boundary

Feb 14     Lecture 17     Mid-Ocean-Ridges – Divergent Plate Margins

Lecture Outline
   Examine triple junctions and their stabilities
   Examine divergent plate boundaries, processes and structures that develop in such regions
   Examine convergent plate boundaries processes and structures that develop in such regions
   Examine transform plate boundaries processes and structures that develop in such regions

Learning Objectives
   to achieve an understanding (at moderate level) of the fundamental processes that takes place in divergent, convergent and transform plate boundaries, and the structures and associations that develop in each boundary

Feb 16     Lecture 18     Subduction Zones – Convergent Plate Margins

Lecture Outline
   Examine triple junctions and their stabilities
   Examine divergent plate boundaries, processes and structures that develop in such regions
   Examine convergent plate boundaries processes and structures that develop in such regions
   Examine transform plate boundaries processes and structures that develop in such regions

Learning Objectives
   to achieve an understanding (at moderate level) of the fundamental processes that takes place in divergent, convergent and transform plate boundaries, and the structures and associations that develop in each boundary
Week 8  
Winter Break – No Lectures

Feb 19  Winter Break  No lecture
Feb 21  Winter Break  No lecture
Feb 23  Winter Break  No lecture

Week 9
Feb 26  Lecture 18  Strike-Slip Zones – Transform Plate Margins

Lecture Outline
Examine triple junctions and their stabilities
Examine divergent plate boundaries, processes and structures that develop in such regions
Examine convergent plate boundaries processes and structures that develop in such regions
Examine transform plate boundaries processes and structures that develop in such regions

Learning Objectives
To achieve an understanding (at moderate level) of the fundamental processes that takes place in divergent, convergent and transform plate boundaries, and the structures and associations that develop in each boundary

Feb 28  Test 2  Term test – lectures 12 – 19 (20% of final grade)

Mar 2  Lecture 20  Sea Level Variations

Lecture Outline
Definition of coordinate systems
Definition of sea level
Causes of global sea level fluctuations
Response of sedimentation to variations in sea level

Learning Objectives
To achieve an understanding of the causes of global sea level fluctuations, and the impact of sea level change to marine sedimentation

Week 10
Mar 5  Lecture 21  Messinian Salinity Crisis

Lecture Outline
Define Messinian Salinity Crisis
Examine sedimentary evidence for the total desiccation of the Mediterranean Sea
Examine the tectonic factors responsible for the Messinian Salinity Crisis
Impact of Messinian Salinity Crisis of global climate

Learning Objectives
To achieve an understanding (at moderate level) of the factors responsible for the Messinian Salinity crisis, the evidence that the entire Mediterranean Sea became desiccated and the impact of the massive salt removal to global climate

Mar 7  Lecture 22  Oxygen Isotopes in Marine Geology

Lecture Outline
Acquisition of the oxygen isotopic signature in shells
Examine how oxygen isotopes can be used to interpret past climate and ocean changes

**Learning Objectives**

- to achieve an understanding of the use of oxygen isotopes as an important proxy for the determination of past changes in global climate and ocean structure and circulation

**Mar 9 Lecture 23 Carbonate Preservation and CCD**

**Lecture Outline**

- Examine the distribution of CaCO₃ in the oceans
- Examine factors controlling the CaCO₃ distribution in the oceans
- Examine how we can determine CCD

**Learning Objectives**

- to achieve an understanding of the preservation state of calcium carbonate in the oceans and the factors controlling this

---

**Week 11**

**Mar 12 Lecture 24 Water Masses in the Oceans**

**Lecture Outline**

- Ionic composition of ocean water
- Residence time of elements and ions in oceans
- Structure of the oceans
- Water masses and their determinations
- Dissolved gases in the ocean water

**Learning Objectives**

- to acquire a moderate level of understanding of (a) the chemical constituents of the ocean and (b) the structure of the ocean water and the delineation of the water masses in the oceans so that the paleoclimatic and paleoceanographic evolution can be properly evaluated

**Mar 14 Lecture 25 Coriolis and Ekman Drift**

**Lecture Outline**

- Definition of Coriolis and Ekman Drift
- Definition of geostrophic currents
- Coastal upwelling and downwelling
- Mid-oceanic upwelling and downwelling

**Learning Objectives**

- to achieve an understanding of the interaction between the atmosphere and the ocean so that zones of increased (or decreased) primary productivity and zones of quasi-permanent upwelling and downwelling in the geological record can be properly evaluated

**Mar 16 Lecture 26 Oceanic Currents**

**Lecture Outline**

- Present-day surface water circulation
- Present-day bottom water circulation
- Thermo-haline circulation

**Learning Objectives**

- to achieve an understanding of the circulation of the surface and bottom waters across the
oceans and understand the boundary conditions of these circulations so that the surface and bottom water circulations during the geological past when the continental masses were radically in different position and orientation can be understood

**Week 12**

**Mar 19**  Test 3  Term test – lectures 20 – 27 (20% of final grade)

**Mar 21**  Lecture 27  Navigation, Geophysical imaging and Geological Sampling

*Lecture Outline*

- Navigation – Geological Oceanographic Research
- Examine the geophysical tools for imaging the seafloor
- Examine the seafloor/subsea sampling tools

*Learning Objectives*

- to achieve an understanding of the methods used in imaging the seafloor and the tools that are used to ground truth the observed images

**Mar 23**  Lecture 28  Estuaries

*Lecture Outline*

- Definition of estuaries
- Classification of estuaries
- Sedimentation in estuaries

*Learning Objectives*

- to achieve an understanding of the differences between various classification of estuaries and the sedimentary processes that take place within estuaries

**Week 13**

**Mar 26**  Lecture 29  Beaches and Barrier Islands

*Lecture Outline*

- Definition of beaches and barrier islands
- Examine beach profiles and processes
- Examine transgressive barrier islands
- Examine regressive barrier islands

*Learning Objectives*

- to achieve an understanding of the formation and evolution of beaches and barrier islands in marine environments

**Mar 28**  Lecture 30  Deltas

*Lecture Outline*

- Definition of deltas
- Examine river-dominated deltas
- Examine wave-dominated deltas
- Examine tide dominated deltas
- Examine longshore current-dominated deltas

*Learning Objectives*

- to achieve an understanding of the formation and evolution of deltas in marine environments
Mar 30  Lecture 31  Continental Shelves and Shallow Seas  
**Lecture Outline**
- Definition of continental shelf and shallow sea
- Examine factors controlling sedimentation
- Examine wave-dominated continental shelves
- Examine tide dominated continental shelves

**Learning Objectives**
- to achieve an understanding of the sedimentation and sedimentary evolution of continental shelves

**Week 14**

Apr 2  Lecture 32  Continental Slopes and Rises  
**Lecture Outline**
- Definition of continental slope and rise
- Morphology of the continental slopes
- Sedimentary processes active on continental slopes
- Mass wasting and its consequences

**Learning Objectives**
- to achieve an understanding of the processes associated with the construction and destruction of continental slopes

Apr 4  Lecture 33  Deep Ocean and Abyssal Plains  
**Lecture Outline**
- Definition of deep oceans
- Examine primary sedimentary processes in deep oceans
  - Pelagic and hemipelagic deposition
  - Deposition via turbidity currents
  - Deposition via bottom currents
  - Deposition via ice rafting
- Examine secondary sedimentary processes in deep oceans
  - Volcanic ash – tephra deposition
  - Authigenic sedimentation
  - Aeolian sediment input
  - Diagenetic deposition
  - Extraterrestrial sediment input

**Learning Objectives**
- to achieve an understanding of the various sedimentary processes active in deep oceanic marine environments

Apr 6  Lecture 34  Overflow  

Date to be decided by MUN  Final examination – lectures 1 – 34 (40% of final grade)
Texts

Because of the breadth of topics covered, there is no single textbook that is adequate for this course. Lecture notes will be available online for each class. Students are responsible for all the material covered in the lectures.

Summary of Learning Objectives

Upon successful completion of this course, the student will be able to show a moderate level of understanding of the following:

- the evolution of the water in the solar system and the origin and evolution of the oceans of the early Earth
- ocean-atmosphere-lithosphere-biosphere interactions and various mechanisms proposed for the evolution of climate in the early Earth
- role that the evolving life played in the radical changes that occurred in ocean chemistry in the Archean Ocean
- (a) early evidences in the development of the Plate Tectonics Theory, (b) driving forces associated with plate movements and (c) the tectonic processes associated with plate margins
- change in the Earth-Moon distance and Paleozoic tides and tidal deposits
- oxygen isotopes in marine microfossils as paleoproxies for past climate and ocean studies
- role of oceans in the transition of the Earth from a Hot House in the Cretaceous to an Ice House in the Quaternary
- ocean acidification and the preservation/dissolution of carbonates on the seafloor
- global sea level variations, their causes and their impacts on marine sedimentation
- desiccation of the Mediterranean Sea during the Messinian Salinity Crisis and the impact of this event in the evolution of the Pliocene global climate and ocean circulation
- show an understanding of the contemporary sedimentary environments, including the estuaries, beaches and barrier islands, deltas, continental shelves, slopes and abyssal plains
- show an understanding of the water masses and their motions in global oceans