University of Toronto at Scarborough
Department of Physical and Environmental Sciences

EESD20

Geological Evolution and Environmental History of North America

Winter 2019: Wednesday 7-9 pm, Room MW160

Professor: Nick Eyles

Teaching Assistant: Shane Sookhan, Ph.D Candidate

Structure of the course and distribution of marks

This course consists of the following components:

1) 12 weekly lectures,

2) A weekend field-trip in March (5 marks for participation) with a group poster presentation on some aspect of environmental geoscience (worth 20% of total marks),

3) An in-class group presentation on some aspect of the geological evolution of North America (25%)

4) A substantive Final Report on the same topic (40%) by the same groups

5) An Abstract of your Final Report presentation is due February 13th at 5 pm and is worth 10 marks and you will receive a mark prior to the drop date of February 25th.

There are no exams in this course.

Introduction

This course reviews the geological and environmental evolution of the North American continent over the past 4 billion years by exploring the range of plate tectonic processes involved in continental growth and how those processes are expressed today as geologic hazards. The course will also review the origins of Canada's natural resources and review changes in terrestrial and marine environments including climate, and the associated ecosystem changes up to the present day. Students will become familiar with recent anthropogenic influences on the environment in regard to waste management, resource extraction and the impacts of urbanization on watersheds on a weekend field trip. This course will provide students with knowledge of naturally occurring long- and short-term environmental changes as context to modern day environmental concerns.

The scientific study of planet Earth is the subject of the discipline called Geology sometimes called Earth Science or Geoscience. The science began as a distinct discipline and profession in Ancient Egypt (many modern geologic terms are thousands of years old) but became globally important in the early 19th century primarily concerned with finding mineral resources such as coal and metal ores for the Industrial Revolution. It subsequently became a pillar of 19th century science by demonstrating the great age of the Earth ('deep time'). This thinking underpinned Darwin's recognition that organisms have evolved through time.

Planet Earth formed about 4.56 billion (000,000,000; abbreviated to Giga annum or Ga) years ago by condensation and accretion of dust and planetary debris. The oldest rocks on Earth are dated at about 4.2 Ga suggesting that continents had already formed. The oldest bacterial life forms occur about 3.5 Ga and an oxygenated atmosphere developed somewhere around 2 Ga before present. Multicellular animal life forms became abundant about 600 million years ago (abbreviated to 600 Ma: mega annum: Ma) an event widely called the 'Cambrian Explosion.' The history of life since has been conditioned by episodic extinction events some possibly created by meteorite impacts.

The hard rocky surface of the planet (the crust) is thick (up to 50 km or more), brittle and broken into large pieces called 'lithospheric plates' that are moved around at velocities up to 25 cm/yr by large convection cells in the hotter Earth's interior (the mantle) below the plates. Alfred Wegener

suggested the drift of continents in 1912 but it was rejected as implausible; how could continents move across solid rock below? Today, it is realized that lithospheric plates slide over hot plastic rocks below constantly changing the appearance of the planet by moving continents around, opening and closing ocean basins. This is called *plate tectonics* and it has been in operation for at least 3.5 Ga. It may not be the only way in which planet Earth functions however and there is increasing recognition of so-called *vertical tectonics* involving giant mantle plumes of hot rock, and the outpouring of enormous volumes of magma (flood basalts, supervolcanoes etc.,) when these plumes reach the Earth's surface. These are called Large Igneous Provinces (LIPs for short). These are common across the Canadian Shield.

Tectonics literally means '*to build*.' Lithospheric plates are formed at so-called 'mid-ocean ridges' (also called 'spreading centers') where new volcanic magma rises to the surface from the underlying mantle and cools to add to the edge of the plate. Continuous addition of new magma and its cooling, results in continuous growth of the plate away and its movement away from the spreading centre (hence its name). This is clearly seen in Iceland today where the mid-Atlantic Ridge is exposed on land and which separates the North American plate from the European plate which are moving in opposite directions away from the spreading centre. The North American landmass is part of the plate and it is moving westward; here in Toronto we are moving at 3.7 cm every year. *In the 50 years that UTSC has been in existing it has moved almost 2 m westward from its original position.* Your home is not where it was last night and will be in a different place tomorrow.

The movement of plates leads to collisions between adjoining plates (called *orogenies*) and destruction of some plates by a process called *subduction* where one plate (usually the oldest and thus thickest) is driven down below the other. This is happening along the west coasts of the Americas and around the Pacific and gives rise to large damaging earthquakes and volcanic eruptions. These are called 'active plate margins.'

The entire plate tectonic process can be likened to a conveyor belt where new crust is created at spreading centers and eventually destroyed by subduction. In this way, the Earth is neither expanding nor shrinking in size. In some cases, orogenic events result in the fusing together of plates (a process called 'obduction') and the creation of even larger plates (called

supercontinents). Geologists have recognized a cycle of supercontinent formation and breakup (the Wilson cycle) which is the basic rhythm of Earth history.

North America's geology and supercontinent cycles

North America's geology reflects events during the formation and breakup of several supercontinents over the last 3 billion years most notably *Arctica* about 2.7 billion years ago, *Rodinia* which formed about 1 billion years ago, and *Pangea* which formed between 400 and 200 million years ago. These episodes were associated with the active growth of North America when new crust was added by plate collisions. Rifting of these supercontinents resulted in the formation of new ocean basins and continued accretion of new crust. The supercontinent cycle forms a simple organizing framework for examining this long history. Planet Earth is currently in a phase of continent dispersal following the breakup of Pangea when the modern oceans first formed. The formation of the next supercontinent (Pangea II) will occur in another 250 million years' time. This basic process is driven by convection of hot rock in the deep mantle (fueled by the heat of radioactive decay) and has been modeled to continue for another 4 billion years. The geological evolution of North America will continue.

The last chapter in North America's long history is that of Pleistocene ice ages of the last 2.5 million years when the northern part of the continent was covered by ice sheets as much as 3 km thick. These had a profound effect on landscapes and left thick glacial sediments that store groundwater and pose complex challenges to construction and geo-engineering.

Environmental geoscience field trip

The course concludes by looking at modern environmental problems in North America revolving around the causes and impacts of climate change, the impact of urban development, disposal of a wide variety of wastes, the clean-up of contaminated sites and waters, and the key role of environmental geoscience. These issues and others will also be examined during a weekend field trip in March when will work as group (maximum 4 students) complete and present a poster worth 20 marks. Your participation on the field trip is worth 5 marks.

Notes

1). The course textbook is *Canada Rocks -the Geologic Journey* available in the Bookstore. It frames the geological history of Canada and Ontario against what is known of modern global plate tectonics. Relevant chapters for each week are shown on the attached lecture schedule.

2). **http://planetrocks.utsc.utoronto.ca** is a web site detailing more than 500 hundred sites of special geological or cultural importance across Ontario. Take a look at it and use it for your poster presentation.

3). Please check the Quercus course site regularly for updates. Shane will be available during regularly-scheduled office hours which he will announce shortly.

4). If you have a disability/health consideration that may require accommodations, please feel free to approach the AccessAbility Services Office who will work with you to ensure you can achieve your learning goals in this course. All enquiries are confidential. The UTSC AccessAbility Services staff members are available by appointment at 416-287-7560 or ability@utsc.utoronto.ca.

5).This course meets the requirements of the Association of Professional Geoscientists of Ontario.

6) Plagiarism will not be tolerated and it is a severe academic offence reportable to the Dean for sanctions. "Normally, students will be required to submit their course essays to Turnitin.com for a review of textual similarity and detection of possible plagiarism. In doing so, students will allow their essays to be included as source documents in the Turnitin.com reference database, where they will be used solely for the purpose of detecting plagiarism. The terms that apply to the University's use of the Turnitin.com service are described on the Turnitin.com web site".

7) Monday, January 21 - last day for students to *enroll* in Winter session courses

8) Monday, February 25 - last day for students to *drop* Winter session courses without academic penalty

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January 2019