University of Toronto at Scarborough
Department of Physical and Environmental Sciences

EES A06: Introduction to Planet Earth

Summer 2018

10 online lectures

Professor Nick Eyles

Note: Professor Eyles is on sabbatical in 2018 and the course will consist of 10 pre-recorded online lectures. The course will be managed by **Dr. Kirsten Kennedy**.

Structure of the course

This course consists of 10 lectures, a mid-term and final exam (each worth 30%), and completion of ten online modules question sets (4% each).

Introduction

Despite what it may appear at times in lectures, this is not a course about motorcycles but is an introductory geoscience course aimed at anyone in the sciences or humanities. If you do like motorcycles so much the better. As a geologist I do a lot of fieldwork in various parts of the globe and I often use two wheels instead of four. If you want to know more about me and what I do I have added a file on BB to go with this course outline. For me life is a journey to see as much of the planet as possible; the idea behind this course is simply to share what I have learned, liked or disliked, with you all in the hope you will begin your own journey.

In this course, you will learn how our planet 'works' by virtual visits to countries in very different geologic settings and by meeting some of the peoples that live in very dangerous areas affected by earthquakes, tsunamis and volcanic eruptions. We will examine how the planet formed and has evolved in the ancient past, how we determine the age of ancient rocks and events and the nature of changing paleoenvironments on the planet over its long 4.5 billion year history. The course will conclude with a brief review of the geologic history of Canada, the importance of natural resources to our economy, and some of the environmental

problems facing our country and world. Simply put, if everyone rode a motorcycle we'd all be better off.

What is geology? Not just rocks

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 the 19th century primarily concerned with finding mineral resources such as coal and metal ores for the industrial revolution in England. It subsequently became a pillar of 19th century science by demonstrating the great age of the Earth ('deep time') which underpinned Darwin's recognition that organisms have evolved through time.

The emphasis on finding scarce resources in a growing and increasingly urban world continues. Today, Geology is also concerned with exploring Earth history and the history of life on earth, and increasingly dealing with emerging environmental issues especially the impacts of climate change and urbanization and the study of scarce water resources. This is a field called 'Environmental Geoscience' which is the focus of a Specialist Undergraduate Program within the Department of Physical and Environmental Sciences (DPES) and a 12 month all-course M.Env.Sc program.

There is a shortage of suitably qualified environmental geoscientists in Canada. The profession requires well-trained individuals and offers many diverse opportunities for a career.

Course content summary

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 even called the 'Cambrian Explosion') and the history of life 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 through solid rock? Today, it is realized that continents are simply part of larger lithospheric plates which move in their entirety over hot plastic rocks below; this process 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).

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 separates the North American plate from the European plate which move 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.

The movement of plates leads to collisions between adjoining plates (called *orogeny*) and destruction of some plates by a process called *subduction* where one plate (usually the oldest) 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 centres 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 recognised a cycle of supercontinent formation and breakup (the Wilson cycle) which is the basic rhythm of Earth history.

Much of Canada's and Ontario's geology reflects events during the formation and breakup of several supercontinents over the last 3 billion years most notably *Rodinia* which formed about 1 billion years ago and *Pangea* (about 400 to 200 million years ago). 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.

Ancient environments are preserved in the form of rocks and by study of the rock record we can reconstruct ancient paleoenvironments. The concept that the present is the key to the past is called *uniformitarianism*. Apart from catastrophic

events like large meteorite impacts that result in widespread extinctions, the concept has served geologists well. We shall examine the history of life on planet Earth and how it reflects broader tectonic and climatic events.

The course concludes by looking at the 4 billion years long geological history of Canada and Ontario including reference to modern environmental problems facing Canadians. We will look at the causes and impacts of climate change, mineral exploration and mining, the impact of urban development, disposal of a wide variety of wastes, the clean-up of contaminated sites and waters, and the key role that environmental geoscience plays in our society.

At the conclusion of this course you will know how planet Earth 'works' regardless of your course of study. This knowledge is key to protecting our complex human world which is subject to natural disasters, the need to protect the environment and to find ever scarcer resources and extract them in an environmentally-sustainable fashion.

Course textbooks and other resources

The course is organized around the 5-part Geologic Journey- World series which aired on Canadian Broadcasting Corporation's 'The Nature of Things' in late 2010 with David Suzuki and myself and *which is available on Blackboard*. It is based on the geology of various parts of the world and you will need to watch these to supplement lectures.

The course textbook is ***Ontario Rocks - Three Billion Years of Environmental Change*** which frames the geological history of Ontario against what is known of modern plate tectonics. The supplemental text is '*Toronto Rocks'*, which is a brief (and inexpensive!) overview of the geology of southern Ontario and environmental issues arising from urban development. 'Toronto Rocks' and 'Ontario Rocks' are available from the bookstore.

In addition, http://planetrocks.utsc.utoronto.ca is a web site detailing more than 700 hundreds sites of special geological or cultural importance across Ontario.

We would also ask you to take a look at *Rock Walk* outside the Arts and Administration Building to honor the 50th Anniversary of the our campus, and which consists of about 50 large boulders of different rock types and accompanying interpretive signage that record changing environments across Ontario over the last 3 billion years. Remember rocks are memories of ancient environments and our only way of knowing what went on millions and billions of years ago.

Also take a look at the real time map of *global earthquakes* on the video display in the Atrium of our new Environmental Sciences and Chemistry building. That's our Earth at work right in front of your eyes.

Evaluation and marks

The course will be evaluated by:

a) Multiple-choice mid-term exam of 100 true/false and multiple choice questions based on lectures 1-7, Geologic Journey videos, assigned chapters of the Ontario Rocks textbook and Planet Earth Modules 1-5
30 marks.

b) Completion of ten Planet Earth Online modules (4% each) which will be released at a rate of one per week. 40 marks

c) 100 question T/F and multiple-choice (*non-cumulative*) final exam based on lectures 8-10, assigned chapters of the Ontario Rocks textbook and Planet Earth Online Modules 6-10 30 marks

You must attend in person to write the mid-term and final exams to complete the course. There are no deferred exams if you miss the mid-term other than for medical reasons; in that case all relevant UTSC paperwork must be completed and submitted.

Things to remember

1. **Please check the Blackboard course site regularly** for updates and commonly asked Questions and Answers. Dr. Kennedy will be available during regularly scheduled office hours which will be announced on Blackboard.

2. Plagiarism will not be tolerated; it is an academic offence and will be immediately reported to the Dean who will issue appropriate penalties.

4. AccessAbility Services: Students with diverse learning styles and needs are welcome in this course. In particular, if you have a disability/health consideration that may require accommodations, please feel free to approach the AccessAbility Services Office as soon as possible. They will work with you to ensure you can achieve your learning goals in this course. All enquiries are confidential. The UTSC AccessAbility Services staff are available by appointment to assess specific needs, provide referrals and arrange appropriate accommodations (416 287-7560) or ability@utsc.utoronto.ca.

Enjoy the course!

Nick Eyles and Kirsten Kennedy
April 2018